GAS JOURNAL, JAN. 8, 1947

VOL. 249 99th YEAR No. 4364

PURIFICATION OF GAS FROM HYDROGEN SULPHIDE

THE discussion which took place following the presentation of the Annual Report of the Gas Research Board at the Autumn Research Meeting of the Institution of Gas Engineers provided an interesting contribution from Mr. J. T. Haynes which has provoked a good deal of discussion on the problem of gas purification and on the relationship of such processes to the work of the Gas Research Board. Mr. Haynes suggested that a research team should be set to work to deal with the purification of gas from hydrogen sulphide by a method other than that now used, and he has whetted our appetite for such work by the intriguing suggestion that in the Burkheiser process "the perfect answer was almost in our hands 20 years ago."

One of the attempts to operate the Burkheiser process was, of course, made at Bournemouth gas-works in, we believe, the days before Mr. Haynes himself was associated with that undertaking. No doubt the recollection of what was there achieved has been handed down and is now seen through the rose-coloured spectacles of time. We are frankly doubtful whether it is completely true to say that the process at Bournemouth "only broke down finally on one factor and that a purely physical one—the iron oxide nodules disintegrated under the repeated changes of temperature." The original nodules were pieces of natural iron ore from a Silesian source and apparently had some peculiar structure for, so far as is known in this country, further supplies could not be obtained. Mr. Haynes has declared, and we have no doubt as to the accuracy of his statement, that the original process worked perfectly except for this one difficulty, and ammonium sulphate and sulphite were produced while the gas was entirely freed from hydrogen sulphide and ammonia.

Our recollection of the process, supplemented by published descriptions of it, is that a particularly active form of iron oxide was desirable such that in the purifiers a gas speed of between 25 and 30 times that ordinarily employed could be maintained, and this permitted the use of much smaller purifiers in a given volume of gas—an important feature of the process. It is only a year ago since Mr. G. U. Hopton and Dr. R. H. Griffith discussed the activity of the various firms of iron oxide and possibly provided the essential information upon which an active form of iron oxide could be produced which would prove the missing link in the Bournemouth process. From this angle there would be much to be said in favour of Mr. Haynes's proposal.

As we have said, however, we have doubts as to whether in fact the Burkheiser process really came as near to success as Mr. Haynes believes. The process as carried out at Bournemouth was, we believe, a dry process in which the oxide nodules had to be revivified by roasting and in that process must keep their size and shape. Unfortunately the supply of the revivification process was very limited and the materials supplied all broke down into dust after the first burning, thereby causing so much back pressure as to throw the plan out of action (P. G. G. Moon, Trans. Inst. Gas E., **79**, 300). It is known that owing to mechanical difficulties Burkheiser himself found it necessary to modify this process and in its final form to make it wet. Although the process was erected in several works, it was not a success. That, however, does not mean that it may not have been near success and it is worth while looking back into the history of gas purification to get some background for any fresh consideration of the process that may be undertaken.

ESSENCE OF THE PROBLEM

IT may be well to remind ourselves at the outset of what the problem really consists. We have no reserves of sulphur in this country and it is desirable from the national point of view to make whatever use we can of our existing sulphur resources rather than having to import. The source of sulphur in this country consists of the gases produced during coal carbonization, the gases produced during the roasting of certain sulphur ores (mainly imported), the recovery of pyrites from coal washeries, which is in operation on some seven plants on the North East Coast, and the gases from large combustion units such as power stations, for which processes have been worked out by Dr. Lessing, I.C.I., and others. The necessity to purify gas from hydrogen sulphide and from ammonia, suggested to many inventors that it should not be necessary to obtain sulphuric acid from a separate plant for this purpose and that it would be very much more profitable to obtain the necessary sulphuric acid from the sulphur already present in the coal and liberated during carbonization. This desirable objective became more important when the coming of synthetic ammonia reduced so materially the profits that had previously been derived from by-product ammonia.

When the earlier attempts to combine ammonia recovery with complete removal of H_2S did not lead to processes which were satisfactory in practice, many inventors began to regard the two processes as separate and to be satisfied if they could recover sulphur in the elementary form. Finely-divided sulphur had special agricultural and other uses for which it would command a high price. The problem may therefore be regarded as two-fold. The ideal process would require no purchase of sulphuric acid from outside but would recover all the ammonia in the form of ammonium sulphate using for the purpose the sulphur derived from carbonization of the coal. Any excess sulphur would be recovered as elementary sulphur if possible, but could be recovered in

oxide purifiers. This is the statement of the problem from the point of view of utilization of ammonia, and in this form it is as much a problem in the economic utilization of by-product ammonia as in the purification of the gas.

The second form which the problem takes is to leave ammonia recovery in its present form while completely removing hydrogen sulphide by a continuous washing process which will avoid the undoubted cumbrousness of the present oxide process. It is perhaps a remarkable dispensation of Providence that the pioneers of the Gas Industry should hit upon the only process so far discovered which permits of the certain, easy, and simple removal of hydrogen sulphide. That that process should have been in use for more than 100 years without any real competitor appearing is conclusive evidence of the difficulty of this second problem.

CONDITIONS TO BE FULFILLED

THE conditions that must be fulfilled by anyone who works on this problem may therefore now be summarized: The process selected must enable complete removal to British Standards of the whole of the hydrogen sulphide present in the gas; the first requirement is therefore a process which will work. Removal of hydrogen sulphide must be conducted with complete certainty and reliability so that it will function at all times and under all conditions that are likely to be met on a normal gas-works or coke oven plant; the second condition is therefore reliability. The third condition is that the process must be economically sound. That means that it must not cost more than the present oxide process and if possible it should show a profit. If the cost is the same as that of the present oxide process, there must be compensating advantages which would secure its adoption. We should be disposed to suggest that the fourth condition must be that of simplicity. The reactions which take place in oxide purification are not necessarily simple—a reaction between a solid and a gas can never be simple physically and it may equally be complicated chemically. The very large number of papers describing the chemistry of the process suggests, in fact, that the oxide process is not simple chemically. It is, however, simple in practice and its simplicity can best be appreciated by considering the exceedingly complicated processes which appear to be necessary if it is to be supplanted. It is admitted that the alternative processes may replace: (a) Ammonia recovery, (b) hydrogen sulphide removal, and (c) sulphuric acid manufacture, but we are convinced that if a process is to be successful at a gas-works it must generally have the merit of simplicity. At the same time it must be remembered that rather more complication can be allowed in the future when smaller gas-works are replaced by large central works, a development which will no doubt come to pass.

Attempts to solve the first of the problems here discussed—namely, the simultaneous purification of the gas from ammonia and sulphur—are quite old. The first worker in this field appears to have been Laming, who just 100 years ago was endeavouring to remove H_2S by means of ammonia liquor and to recover the H_2S in concentrated form by subsequent distillation. Since then there has been a long series of attempts made in the most highly industrialized countries of the world to solve this problem of complete wet purification of gas. It is probable that up to about 1930 the most promising of these processes was that of Burkheiser, in which ammonium bisulphate and bisulphite were used to absorb ammonia. In the Burkheiser process as existing in 1932 (according to Gluud, "Handbook of the By-Product Coking Industry"), the crude gas freed from tar was washed with iron oxide and sulphur in aqueous suspension, thereby forming iron sulphide. The solution was mixed with concentrated ammonia liquor when the free sulphur was dissolved to form ammonium polysulphide. The solid ferrous sulphide was allowed to settle out and after revivification with air the resulting iron oxide and sulphur were suspended in water and again used for washing the gas from hydrogen sulphide and hydrogen cyanide. The clear liquor was heated in an evaporator to 95° C. with liberation of ammonia and hydrogen sulphide (which were condensed in the usual way and formed the concentrated ammonia liquor required above) and deposition of sulphur, which was centrifuged, and burnt to sulphur dioxide; sulphur dioxide, air, and ammonia formed in solution a mixture of bisulphate and bisulphite used for absorbing ammonia from the gas with formation of sulphate and sulphite which, being much less saleable than the acid salts, could be crystallized out in a suitable saturator.

By comparison with the normal oxide purification process, this sounds complicated and suited only to very large works. Gluud's observation is worth recalling: "The development (of the Burkheiser process) has lacked the success expected. It is also rather complicated, one of its main drawbacks being that the conversion of ammonium sulphite into sulphate could not be effected. . . . On the whole, complicated and sensitive processes are not very promising, due to their being a continual source of anxiety to those in control. Every departure from the normal disturbs the distribution of the gas as well as the operation of the by-product plant, so that the removal of hydrogen sulphide, hydrocyanic acid, and ammonia must be carried out in a simple and reliable manner. If it is necessary to employ complicated processes which have been satisfactorily proved to be of sound economy, then they should only be used on those parts of the plant which are independent of the gas circuit." There is a good deal of sound common sense in this statement. Not only was the Burkheiser process complicated, but it still required a great deal of fundamental physico-chemical research to establish it on a sound foundation. In particular, a close study was needed of the conditions which would have permitted the formation of ammonium sulphate instead of a mixture of this salt with sulphite.

MIXED OPINION

THERE are differences of opinion as to whether the mixture of ammonium sulphite and sulphate produced in the Burkheiser process was satisfactory as a fertilizer and views have been expressed that even small quantities of sulphite had an adverse effect on vegetation. M. Brabant, writing in 1942 in the *Bulletin de l'Association des Gaziers Belge*, said that the extent of the equipment required, the high maintenance costs, and the death of the inventor caused the abandonment of the Burkheiser process. Recently, he said, Terres and Heinson have investigated the partial pressures of sulphite dioxide, ammonia, and water vapour and the equilibrium resulting from the absorption of ammonia and sulphur dioxide in a solution of ammonium sulphite and bisulphite and have concluded that the process is practicable. It may be practicable, but there is no certainty that it would be economic.

The Feld process obtained a good deal of notoriety about the same time as the Burkheiser process. It was not successful because it did not free the gas completely from hydrogen sulphide and the plant was subject to severe corrosion. The washing liquor contained ammonium polythionates which absorbed the ammonia and hydrogen sulphide from the gas and produced ammonium thiosulphate and sulphur. The thiosulphate was reconverted with sulphur dioxide into polythionates and a part of the solution was transformed by heating into ammonium sulphate and sulphur, a portion of this sulphur being used to supply the necessary sulphur dioxide. From this process was developed the Koppers C.A.S. process, which may be described as the most expensive failure in the history of this work. We do not propose to endeavour to describe this process in full. Like many other processes it worked successfully on the small scale and its theoretical basis was perfect. At a time when Dr. Koppers had built two plants costing over £500,000 with a

guarantee to pull the plants out without cost if unsuccessful, an unexpected difficulty in finding a metal that would be non-corrosive for one vital stage in the process, coupled with a disastrous fall in the price of sulphuric acid, caused the process to be abandoned with the loss of the whole of the money invested in the plant and perhaps almost as much invested in previous researches. Since that time there have been very many processes, many of which have been built on a large scale and have been reported as working with varying degrees of success. There seems, however, to be always found some snag, because with certain exceptions few of these processes are built and operated on more than one or two works. Within recent years the emphasis seems to have swung on to the second of the two problems we have propounded—namely, the removal of hydrogen sulphide by continuous process and its recovery as elemental sulphur.

A VARIETY OF PROCESSES

THE Seaboard process was the first liquid purification process to be widely used but was unsatisfactory because the sulphur was discharged into the atmosphere. It was, however, adopted for some 60 works in America; it consisted, of course, in scrubbing the gas with a 3% solution of sodium carbonate from which the sulphur was removed by blowing with air. It was succeeded by the Ferrox process which used a 1-2% soda ash solution with ferric hydroxide in suspension. Aeration of the spent liquor caused free sulphur to separate but the sulphur was too much contaminated with iron to be saleable in competition with the natural product. The most expensive of the sulphur recovery processes is the Thylox process which is very largely used in Germany and Japan. In this the hydrogen sulphide is recovered by absorption in solution of ammonium thioarsenate which can be revivified by blowing with air. It is claimed that by using a double absorption tower hydrogen sulphide can be removed down to British standards, though the process is more economically conducted by removal of 95% of the hydrogen sulphide in the Thylox system with an oxide catch-box for the remainder. This system in itself illustrates one of the fundamental difficulties in the economics of any flow system. The oxide purifier requires very little man-power and operates day after day with nothing more than supervision until the oxide must be changed, when a purely temporary gang of men is got together for the purpose. In a continuous process it is generally necessary for one or more men to be present throughout the whole 24 hours, and this leads to very much higher labour costs than with the oxide process.

The Thylox process, we are given to understand, is economic on a very large scale and can even produce sulphur at a profit. It is unsuited for small-scale work, however, on account of the difficulty of labour costs. There are newer processes which have not yet achieved anything like the popularity of the Thylox process, such as the Girbotol amine absorption process using diethanolamine and the sodium phenolate process. The Girbotol process is based on the principle that cold solutions of various organic amines can dissolve large volumes of acid gases such as hydrogen sulphide and carbon dioxide, these gases being removed by treatment with steam at 250°F. In the American Koppers sodium phenolate process the absorption of hydrogen sulphide takes place with formation of NaSH and liberation of phenol, a reaction which is reversed by steam heat. Both of these processes liberate hydrogen sulphide at very high concentration from which sulphur can be manufactured separately.

A later development of the original Burkheiser idea is the Katasulph process, for which considerable success has been claimed. It is based upon catalytic selective oxidation of hydrogen sulphide in the presence of other oxidizable constituents in coal gas. The sulphur dioxide so formed then combines with the ammonia in the gas, the ammonium sulphite being recovered by washing and converted to sulphate and free sulphur by heating in an autoclave. The ammonium sulphate is recovered by evaporation. This process, according to present information, does not appear to extract the last traces of hydrogen sulphide from the gas.

It would be possible to write at considerable length on the development of gas-washing chemical processes. Many well-known processes have not been mentioned here. It will be sufficient for our present purpose to place on record the great number of serious attempts, made not only in the laboratory but translated to a considerable works scale, to solve this intricate problem. Processes for the removal of hydrogen sulphide from gas can be divided into two broad groups: (1) oxidation processes in which the object is to produce sulphur (e.g., the existing oxide process and the Thylox process), and (2) processes which remove the hydrogen sulphide as a sulphide or polysulphide and yield it up again as a gas at a later stage (Seaboard, Girbotol, &c.).

RELIABILITY AND SIMPLICITY

PROCESSES which are successful under foreign conditions such as in U.S.A, pre-war Germany, or Japan, will not necessarily meet British conditions. The British gas engineer is not fundamentally a chemical engineer and he has less use for chemistry than his colleagues in the chemical industry proper. When the new central plants are built, we suppose that there will be room for a chemical engineer as well as a gas engineer. The door will then be open for the development of these rather elaborate chemical processes. The gas engineer, meanwhile, has one basic duty—to keep the gas supply going and to provide gas under the right conditions and of legal and adequate purity at all times. He requires a process conforming to the conditions we have laid down. Simplicity, sureness, and reliability must be the key-notes. The gas must be washed with a solution that is readily obtainable and which within the limits of a normal washing plant can and will remove with certainty all traces of hydrogen sulphide. The working-up of the washing solution will depend on the size of the staff available. On a large works able to support chemists and chemical engineers, this process can be elaborate and complicated provided it is economic and provided that a supply of revivified washing liquor can be readily made available. For smaller works, no such elaboration can be permitted.

If the need for reliability and simplicity places one limit on the development of continuous washing processes, another and possibly greater limitation is that of cost in relation to the cost of oxide purification. Such processes as sodium phenolate and diethanol amine appear simple enough to form the foundations for a British process, provided that they will remove all the hydrogen sulphide with certainty. But what is the cost of renewal of such washing material as is inevitably wasted in practice? Labour charges, except in really large works, make it essential that the plant will work by automatic control and with only occasional attention from the foreman or other operator.

Viewed in this light, the prospects of liquid purification do not appear promising. But we do not profess to have said the last word on the subject. Let this be a starting-point only. The next step may well be an economic appraisement of the cost factors involved. Bearing in mind the present cost of hydrogen sulphide removal and of all the costs involved in ammonia recovery as sulphate, what costs per therm of gas can be permitted? An authoritative statement of the economics of the subject would do much to assist inventors. A good deal more appears to be needed than the discovery of "a method of producing nodules of active iron oxide which will stand up to repeated violent changes of temperature without disintegrating" as was suggested by Mr. Haynes. But we quite agree that it is time someone found a more convenient process than the clumsy, ancient—but still not out of date!—oxide box.

Personal

New Year Honours

Noteworthy names among the recipients of New Year Honours announced last Wednesday were those of Mr. CHARLES DUKES, who is raised to a Barony ; Dr. E. W. SMITH, who becomes a Knight ; Sir FREDERICK WEST, who receives the G.B.E. ; and Mr. JAMES JAMIESON, who becomes a C.B.E.

Mr. CHARLES DUKES, until recently General Secretary of the National Union of General and Municipal Workers, a member of the General Council of the Trade Union Congress since 1934 and Chairman in 1945, is Chairman of the National Joint Industrial Council for the Gas Industry, of which he became a member in 1934, and Vice-Chairman a few weeks later. When the late Sir David Milne-Watson retired from the Chairmanship of the Council in 1944 Mr. Dukes succeeded him.

Dr. ERNEST WOODHOUSE SMITH, C.B.E., has, as is well known, spent most of his lifetime in the Gas Industry. After serving the Birmingham Gas Department for several years he joined the Woodall-Duckham Companies in 1920 and later became Technical Director. In October, 1941, he was appointed to the newly-created post of Director-General of Gas Supply, a position which was abolished when he resigned early in 1943. In the following year he resigned his Directorships of the Woodall-Duckham Companies to devote himself to public work, and he recently retired from the Presidency of the Institute of Fuel, a position he had held with distinction for a record length of time. Dr. and Mrs. Smith have received many letters of congratulation and will reply to them in due course.

Dr. E. W. Smith, C.B.E., who has received a Knighthood.

Sir FREDERICK J. WEST, Chairman and Managing Director of West's Gas Improvement Co., Ltd., Manchester, receives his G.B.E. in recognition of his services to the Ministry of Labour and National Service. He has long taken a prominent part in the national affairs of the Gas Industry, and was President of the Institution of Gas Engineers in 1942.

Mr. JAMES JAMIESON receives his C.B.E. at the close of the active phase of a long career in the Gas Industry, the last 26 years of which have been spent in the Edinburgh Gas Department, 13 as Engineer and Manager. His retirement was announced in the "JOURNAL" last week. Mr. Jamieson is also a Past President of the Institution of Gas Engineers. The annual meeting in 1944, his year of office, was to have been held at Edinburgh, but war circumstances, particularly the preparations for "D" Day, necessitated its cancellation.

Other New Year Honours include the K.C.M.G. for Sir JOHN B. FORBES WATSON, Director of the British Employers' Confederation; the C.B. for Mr. F. C. STARLING, until recently Under Secretary, Ministry of Fuel and Power; the C.B.E. for Dr. T. D. JONES, Professor of Mining, University of Wales, and Director of the Mining Research Laboratory, Cardiff; the O.B.E. for Mr. R. G. THATCHER, Principal, Ministry of Fuel and Power; and the M.B.E. for Mr. J. C. CARSON, Director of the Coatbridge Gas Company, for his work in connexion with timber production, Mr. J. EDWARD, Regional Fuel Engineer for Scotland, Ministry of Fuel and Power, and Mr. J. ROUSE, Staff Officer, Ministry of Fuel and Power.

* * *

Dr. E. V. EVANS has been elected a Director of the Brighton, Hove and Worthing Gas Company to fill the vacancy caused by the death of Lord Cautley.

Mr. J. PARKER and Mr. E. H. WALTON, who have been in the service of the Newcastle and Gateshead Gas Company for 47 years and 50 years respectively, have retired and have been presented with wallets of Treasury notes.

* * *

Mr. HAROLD G. PALMER has resigned the Chairmanship of the Imperial Continental Gas Association and has been appointed Deputy Chairman. Sir GEORGE JESSEL, Bt., M.C., who was previously Deputy Chairman, has been appointed Chairman.

* * *

Mr. J. G. O. DRAKE, F.L.A.A., A.C.I.S., has been appointed Sales Manager and Deputy Secretary of the Liverpool Gas Company, and Mr. J. E. POWERS, F.C.W.A., has been appointed Office Comptroller. Mr. Drake was previously Treasurer and Deputy Secretary and Mr. Powers was Cost Accountant. The appointments date from Jan. 1.

* * *

Mr. B. J. DEAKIN, of Burgh-le-Marsh, Lincs, Manager of the Burgh gas-works until their closure in 1928, celebrated the 59th anniversary of his wedding on Christmas Day. Before going to Burgh, Mr. Deakin was Manager of gas-works at Leavesden, Herts, of the Metropolitan Asylum Board for 17 years and at Mildenhall, Suffolk, for five years.

* * *

Miss A. E. R. ASHTON, M.C.A., formerly Assistant in the Home Service Section of the Manchester Gas Department, has been appointed Senior Home Service Adviser and Cookery Demonstrator to the Stretford and District Gas Board. With this appointment, the Board re-introduced their Home Service Department and held a series of Christmas cookery demonstrations at its district showrooms. Satisfactory audiences were present at these demonstrations.

* * *

Mr. TREVOR A. MORGAN, C.A., Assistant Secretary of the Cardiff Gas Light and Coke Company. has been appointed Secretary of the Company upon the relinquishment of this office by Mr. ROBERT J. AUCKLAND, F.C.I.S., Director, Manager, and Secretary. Mr. Auckland will continue as Director and Manager of the Company. Mr. Trevor Morgan, who is a member of the Society of Chartered Accountants in Edinburgh, first joined the Cardiff Company as Internal Auditor after serving his articles with Messrs. Jones, Robathan, Thompson & Co., Chartered Accountants.

* * *

Mr. ALEC E. WHITCHER, M.I.Mech.E., retired at the end of the year from the position of Managing Director of the Haywards Heath District Gas Company, although continuing as Deputy Chairman. He was appointed Engineer, Manager, and Secretary in 1919, when the output of gas was some 50,000,000 cu.ft., whereas in 1946 the Company produced 220,000,000 cu.ft. During his 27 years at Haywards Heath, the works have been entirely remodelled; he acquired the Balcombe and Cuckfield Gas Companies and extended high pressure mains to the villages of Ardingly and Handcross. Mr. Whitcher is succeeded by the promotion of two of his chief officials. Mr. SPENCER H. COX, Works Manager, becomes Engineer and Manager, and Mr. HENRY ORCHARD Secretary. Mr. Cox presided over a full gathering of the staff and workmen in the Company's Demonstration Theatre on New Year's Day, when the Works Foreman, Mr. W. Wingham, with 50 years' service to his credit, presented on their behalf to Mr. Whitcher a silver salver suitably inscribed.

* * *

From Jan. 1 Mr. MICHAEL MILNE-WATSON took over the duties of Governor of the Gas Light and Coke Company in succession to M. A. E. Sylvester, who has retired, after a little over two years in the chair, for health reasons. Mr. Milne-Watson, who at 36 is the youngest Governor the Company has had since its inception in 1812, thus steps into the position which his father, the late Sir David Milne-Watson, filled with such conspicuous ability from 1918 to 1944. He entered the service of the Company 13 years ago. His father became Assistant General Manager when he was 28 and had been with the Company for 21 years before he succeeded the late Mr. John Miles as Governor. The new Governor's appointment is the first instance in the long history of the Company of a son attaining to the position filled previously by his father.

Mr. PETER BLAIR is retiring after nearly 35 years service as Representative of W. and B. Cowan in the North of England.

* * *

Mr. D. S. DAVIES, Engineer and Manager of the Porthcawl Gas Department, has been appointed the Engineer and Manager of the Abertillery Gas Department and will take up his new duties on Mar. 1.

* * *

Mr. P. B. NICHOLSON has retired from the position of Coke Oven Manager at Cortonwood Colliery, which he has held for 31 years. He is a Director of the South Yorkshire Gas Grid Company, and Vice-Chairman of the South Yorkshire Coke Oven Owners' Association and will retain his public appointments.

* * *

Mr. GEORGE IRVING, who represented Walworth, Ltd., in the Midlands and West Country, retired on Dec. 31 after a long period of service with the Company. He began in 1890 with their predecessor, H. Munsing, as a warehouseman, but since 1908 has been an outside representative. From 1921 to 1927 he was Manager of the Glasgow branch, and since 1927 has made Birmingham his headquarters.

* * *

Newport (Mon.) Gas Company has appointed Mr. T. EDWARDS as Distribution Engineer, Major L. H. LEYLAND, Domestic Sales Manager, and Mr. IRVING CARLESS as Fittings Inspector. Mr. Edwards and Major Leyland fill posts created because of the Company's greatly extended business, while Mr. Carless is promoted to a position previously held by Mr. Edwards. Going direct from school about 20 years ago, Mr. Edwards and Mr. Carless received their practical training with the Company, and continued their studies in gas-fitting classes at Newport Technical College. Mr. Edwards is now teacher of gas-fitting at the College. Major Leyland was in the Company's service before joining the Forces in August, 1939, and has returned after seeing considerable service in Africa and Europe. He was mentioned in dispatches.

Obituary

The death has occurred of Mr. G. N. MATTHEWS, of Gateshead, who was in the service of the Newcastle and Gateshead Gas Company for 54 years.

1947 "Journal" Directory

The following changes in the "JOURNAL" Calendar and Directory were received too late for inclusion in the 1947 Edition, which should now be in the hands of most of our readers. The various changes notified during the year will be listed in the first issue of the "JOURNAL" in each month so that those who wish to keep the Directory up to date may note them from time to time.

Page 6.—ALNWICK. Delete C. Turnbull, *S.* (deceased).
" 10.—BATH. C. Bateman, *D.*, *G.M.*
" 14.—BRIGHOUSE. J. G. Tilley, *E.* and *M.*, resigned.
" 20.—CHERTSEY. F. G. Matthews, *E.* and *M.*, retired.
" 26.—DEVON GAS ASSOCIATION. K. G. Pemberton, *E.*
" 28.—DUNSTABLE. H. C. Smith, *Dep.Ch.* and *M.D.*
" 32.—GAS LIGHT AND COKE COMPANY. M. Milne-Watson, *Governor* and *M.D.*, vice A. E. Sylvester; F. M. Birks, *Dep. Governor* and *M.D.*
" 36.—HEREFORD. A Facer, *E.* and *G.M.*, vice A. Roberts, retired.
" 40.—EAST HULL. J. G. Tilley, *E.* and *Asst.M.*, vice J. R. Martindale.
" 44.—LEEK. S. T. Jones, *E.* and *M.*, vice D. K. Green.
" 44.—LEYLAND-ORMSKIRK GROUP. S. P. Kermode, *S.*
" 48.—MARKET RASEN. H. Critchley, *S.*
" 50.—MARPLE. J. R. Fleming, *E.* and *M.*
" 50.—MARSDEN. J. H. Clegg, *E.* and *M.*, resigned.
" 56.—OSWALDTWISTLE. J. H. Clegg, *E.* and *M.*, vice S. T. Jones.
" 70.—STRATFORD-ON-AVON. D. K. Green, *E.* and *M.*, vice F. Shewring, retired.
" 74.—TOTTENHAM. E. C. Woodall, *Ch.* and *M.D.*; H. C. Smith, *Dep. Ch.* and *M.D.*
" 86.—BATHGATE. J. S. McLaren, *E.*, *M.* and *S.* Delete A. Torrance, *S.*
" 88.—BURNTISLAND. D. Marshall, *E.* and *M.*, resigned.
" 88.—DOUNE. D. Gold, *E.* and *M.*, resigned.
" 90.—EDINBURGH. J. Jamieson, *E.* and *M.*, retired.
" 92.—INVERBERVIE. C. Milne, *M.*, vice A. S. Keay, retired.
" 92.—KINGSKETTLE. D. Gold, *M.*, vice D. McD. Kerr.
" 94.—MILLPORT. L. Nicol, *E.* and *M.*, vice J. Dymock, retired.
" 96.—PAISLEY. D. Marshall, *Dep.E.* and *M.*, vice A. Facer.
" 100.—COLERAINE. W. R. Armstrong, *E.* and *M.*
" 141.—SOUTH AFRICAN LIGHTING ASSOCIATION. R. V. Hart, *E.* and *M.*

Diary

Jan. 10.—London and Southern District Junior Gas Association "Consumer Service—Deeds, not Words," J. A. Marwick. Gas Industry House, 7 p.m.
Jan. 11.—Scottish Junior Gas Association (Eastern District): Short Paper Day.
Jan. 13.—Women's Gas Council: Executive Committee, Gas Industry House, 1 p.m.
Jan. 14.—British Gas Council: Central Board, Gas Industry House, 2.30 p.m.
Jan. 14.—National Federation of Gas Coke Association: General Committee, Gas Industry House, 10 a.m.
Jan. 14.—Midland Junior Gas Association: "The Distillation of Tar and Benzole," Roland Scott (Midland Tar Distillers, Ltd.).
Jan. 15.—B.G.C. Domestic Development Committee. Gas Industry House, 2 p.m.
Jan. 16.—Solid Smokeless Fuels Federation: Executive Committee, Dorchester Hotel, 11.30 a.m.
Jan. 18.—Manchester and District Junior Gas Association: "Corrosion on Gas-works," A. J. Brandram (United Kingdom Gas Corporation).
Jan. 22.—London and Southern District Junior Gas Association: Visit to Neasden Works of Ascot Gas Water Heaters, Ltd.
Jan. 23.—Industrial Gas Development Committee, Gas Induatry House, 10 a.m.
Jan. 25.—Western Junior Gas Association: Prospective Industrial Paper.
Jan. 25.—Yorkshire Junior Gas Association: Discussion, Wakefield.

"JOURNAL" CALENDAR AND DIRECTORY

Distribution has started of the 1947 Edition of the "GAS JOURNAL" CALENDAR AND DIRECTORY, and those subscribers who have not already received their copies may expect them within the next few days. The compilation of this unique directory of the Gas Industry is always a fascinating, if arduous, task, and it has been more so on this occasion for two reasons. We have been able, for the first time since 1939, to include practically all the information which came under the war-time security ban, and secondly, improvements have been made in the presentation of the various sections, one result of which is that, while the contents are conveniently divided, an old difficulty regarding pagination has been removed and the numbering becomes consecutive throughout the 541 pages. With the co-operation of the chief officials, which we cordially acknowledge, the particulars of every gas undertaking have been revised so as to present a true picture of the personnel, capital, plant, make, declared calorific value, operational results, consumers, sales, and prices, up to the day of going to press. Consumers have been re-classified under "Domestic" and "Non-Domestic," and sales for the first time are shown as percentages under three headings, "Domestic," "Industrial," and "Commercial." A list of by-product coke oven plants in Great Britain—one of the items to which the Censor took proper objection during the war—reappears in revised form, and all the latest changes in gas and allied organizations, and in the holding companies, are included.

The Handbook—a memorandum of gas-works practice with general information and tables for daily reference in the gas and allied industries—has come under extensive revision. Among the more notable features of this section are the review of current legislation and entirely new information on organic sulphur removal and on gas utilization. The last-named section contains the recommended best practice in installation and utilization work set out in the Report of the Gas Installations Committee (Post-War Building Study No. 6) and in the several Codes of Practice issued by the British Standards Institution for the Codes of Practice Committee for Civil Engineering and Public Works. The whole of the contents of the Handbook have, so to speak, been "tightened-up." The information is definitely 1947.

The trade sections once again reflect the confidence of gas-works contractors and makers of plant and appliances in the continued prosperity of the Gas Industry. The aggregate advertising maintains our previous high record and at the same time sets up a new standard of colour presentation. Frankly we are not ashamed of the results of our efforts, but we are conscious of our human limitations, and if, in the process of perusing their copies of the CALENDAR AND DIRECTORY any of our readers detect ground for criticism or comment, we shall be very pleased to hear from them.

News in Brief

The First Cargo of Coal to arrive there for three years has just reached the port of Sligo. It came from Silloth, and is for the use of the Sligo Gas Company.

Glasgow Gas Department is to supply the Corporation Housing Department with 2,500 cream and black gas cookers, 2,500 grey dappled gas cookers, 10,000 cornice side extension pieces, and 5,000 " Embassy " wash-boilers.

The Christmas Output of gas at Belfast was a record. Between 12 noon and 1 p.m. on Christmas Day 1,837,000 cu.ft. of gas was used—an increase of 11.6% on the previous record hour. The output on Christmas Eve and between 9 a.m. and 3 p.m. on Christmas Day showed an increase of 10.6% over the corresponding hours of 1945.

Accrington District Gas and Water Board has received permission from the Ministry of Fuel and Power to increase the price of gas by 1d. per therm for domestic and industrial uses, representing a 10% increase to domestic users, but a higher percentage increase to industrial users, who are on a cheaper rate. This is the second increase since the war began. The first was one of 10% in January, 1942.

Trade Statistics for September, 1946, just issued by the Department of Industry and Commerce in Eire, show imports of 23,255 tons of gas coal, valued at £68,700, against 16,564 tons, valued at £48,409, in September, 1945. This brings the total of these imports for the first nine months of 1946 to 194,577 tons, valued at £568,700, against 147,090 tons, valued at £409,558, in the corresponding period last year.

The Request of Bolton Corporation for authority to increase the price of gas has been refused by the Ministry of Fuel and Power. Gas employees had been granted an increase in wages as from April, and the suggested revised price was to cover the deficit. The estimated deficit, Mr. H. Platt, Engineer and Manager, reports, is not likely to occur; an increase in consumption will balance the accounts. The price of Bolton's gas was last increased in 1945.

Increased Working Costs, mainly for coal, are quoted by Shipley Council as the cause of an increase in the price of gas used for domestic purposes. Gas supplied through ordinary meters will be increased by 1½d. to 1s. 2½d. a therm from the meter reading for the end of the half-year to Dec. 31. Gas supplied through pre-payment meters will be decreased from 15 cu.ft. for a penny to 13 cu.ft. These increases restore domestic gas prices to the 1940-44 level.

Polmont District Gas Compny has been refused permission by the Secretary for Scotland to extend its gas undertaking, and has been informed that it should draw additional supplies from the municipally-owned gas supply undertaking at Falkirk. Falkirk Town Council has agreed to grant this supply at a cost of an annual payment of £113 to cover standing charges in respect of an 8 in. main approximately 700 yards in length, and a charge for gas supplied at a rate of 3s. 1½d. per 1,000 cu.ft. Polmont Gas Company has indicated its willingness to accept these terms.

Brides and Brides-to-be have been taking a course in cookery at Newport (Mon.) Gas Company's showrooms for the past 13 weeks, and at a Christmas party to their instructress they demonstrated what can be performed with present-day rations by preparing a sumptuous buffet for the occasion. Sixty young cooks have profited well from the training given by Miss Florence Davies, the Gas Company's cookery instructress. This class was the first of its kind, though Newport Gas Company regularly give cookery demonstrations at their showrooms. Now that the cookery class is over it is hoped to hold a new class in housewifery in the new year.

Joint Consideration is being given by the Gas Committees of Birmingham and Coventry Corporations to the supply of gas to the area lying between the two cities. Owing to the great demand on its gas supply resources, Birmingham has proposed that Coventry should undertake the supply of this area. During the war Coventry gas undertaking's manufacturing capacity was increased by 70% by the installation of modern plant, at a cost of £600,000. On peacetime demand the undertaking can supply a much larger area than its present area of supply. Despite rising costs of labour and materials, the price of gas sold by Coventry is at 4s. 7d. per 1,000 cu.ft., only 40% above the pre-war selling price.

Two 100 ft. Long Gas Ovens have been installed by the United Co-operative Baking Society, Ltd., in their new mechanized bakery in McNeil Street, Glasgow. This bakery, one of the most modern in the world, is the first complete unit of its type to be built since the war in Britiain. The ovens are 100 ft. long by 9 ft. 8 in. wide with " Cyclotherm " heating throughout. There are four heaters with gas burners and electric circulating fans mounted on the top of the ovens and circulating hot gases to radiators in the baking chamber arranged above and below the oven plate. Gas heating equipment and thermostatic control permit precise management of the bake along its travel. The entire equipment was installed by Baker Perkins, Ltd.

Dalkeith Gas Light Company is to increase the price of gas by 10d. per 1,000 cu.ft., making the new charge 5s. 5d.

Middlesbrough Gas Department broke all records in the history of the undertaking last month. On one day they sent out 8½ million cu.ft. of gas.

George Wilson Gas Meters, Ltd., have opened a small branch at Merridale Works, Merridale Street, Wolverhampton, with the object of affording improved service in that area.

Horncastle Gas Department has provisionally fixed the price of gas as from April 1, 1947, at 5s. 10d. per 1,000 cu.ft. At present quarterly consumers pay 5s. plus meter rent and prepayment consumers get a rebate.

An Attractive Gross Price List has just been issued by Wellington Tube Works, Ltd., Tipton. This new list covering tubes and fittings should prove of considerable value to all buyers as it is complete with all revised extras and allowances.

The Spring General Meeting of the Southern Association of Gas Engineers and Managers will be held at the Connaught Rooms, Great Queen Street, London, on May 20. In making this unusually early announcement the Secretary states that considerable trouble has been taken in fixing the date well in advance, in order to avoid the fixing of meetings of other gas organizations on the same date.

A Further Warning that if the present high rate of gas consumption continues, more drastic steps than the present slight reduction in pressure might be necessary has been issued by Glasgow Gas Department. Despite the recent appeal, consumption in the city, and the surrounding districts supplied by the Corporation, has continued to rise. Recent outputs were nearly 10% higher than last year. On one day 44.7 million cu.ft. were consumed.

A Grand Carnival Christmas Party at the invitation of Mr. Leopold Friedman and the Directors of De La Rue Gas Development, Ltd., provided one of the happiest evenings of Christmastide. It was held at Porchester Hall, Bayswater, on Dec. 20. Members of the Board and the staff and employees, with their friends, were present in full force, and the guests also included many members of the Gas Industry. George Melachrino and his Swing Octet provided the music, and the dancing was under the direction of Mr. L. W. Davison.

Lanark County Council Gas Undertaking is supplying gas to the new experimental housing scheme, now in course of erection at O'Wood, Holytown. The Scottish Special Housing Association is building the houses on a site adjoining the large industrial estate at Newhouse. The first 26 houses have gas cookers, wash boilers, and boiling-water sink heaters installed. There is also a point for a gas poker, which is supplied free by the Gas Department, and this point can also be utilized for a portable gas fire. In view of the experimental nature of this scheme, the tenants reactions to gas as a fuel for cooking and heating will be closely studied, and their criticisms will determine the fuel which will be used in the remainder of the scheme.

Residents in New Housing Areas in Edinburgh will be interested to hear of the appearance of a travelling showroom-lecture " hall " capable, after alterations, of accommodating some 50 persons. The portable showroom is to make its debut under Corporation auspices at Muirhouse, where it will be used for cookery demonstrations carried out by the Ministry of Food in association with Edinburgh Gas Department. Should the residents show due appreciation of the service, there is a possibility that the Public Health, Education, and Parks Department will make use of the vehicle as a lecture hall for their respective services, each department doing a tour of the various housing schemes where halls are few and far between. In that case the co-operation of the various tenants' associations would be sought to ensure a measure of public interest that would justify the necessary expenditure.

There is in the Gas Industry a new spirit of scientific enquiry, and in the application of science to the manufacture, distribution, and utilization of fuel. Much work has been done by organizations within the Gas Industry, such as the Industrial Gas Centres and by laboratories owned by gas undertakings, or by firms that design, build or manufacture plant and appliances for the Industry. A great deal of this work has been gathered together and consolidated through the Institution of Gas Engineers and Gas Research Board. New processes are being devised for the manufacture of gas and some of these are already at the pilot plant stage. The Gas Research Board is likely to develop in size and scope during the next few years. Gas has become one of the most scientific industries in the country. . . . There can be no doubt that coal carbonization as practised in the Gas Industry and the coking industry to-day is one of the most valuable activities in the country.—Mr. J. R. W. Alexander in the Silver Jubilee Number of the *Fuel Economy Review*, published by the Federation of British Industries.

Quartz in Fireclay Refractories*

By J. SHARP SMITH, B.Sc., D.I.C., A.M.I.Chem.E., and PETER F. F. CLEPHANE, M.Sc.
(Gas Light and Coke Company)

THE object of this Paper is to draw attention to a behaviour of refractory materials which, though noted in the literature, seems to have had its importance overlooked by both producers and consumers. The point at issue is the reaction between quartz and clay, which under certain conditions takes place readily at high temperatures.

This work arose out of several failures of refractories, some of which were quite serious. One involved the material of the retorts in horizontal settings; another, the arches at regenerator level in horizontal settings; and a third, the backs of coke fires. All these failures were traced to the occurrence of the reaction between quartz and clay.

Normally the amount of quartz in fireclay products is of the order of 5% to 7%, though some manufacturers produce goods of a consistently lower content.

Fireclay material with a high quartz content usually shows a high contraction when subjected to the standard I.G.E. permanent linear change test. Table 1 gives particulars of deliveries of fireclay received at Beckton during the years 1944 and 1945. For the sake of brevity, only six sources have been included. Several other products were equally as satisfactory as that from Source 2.

It is not our purpose to discuss the origin of quartz in fireclay, except to suggest that difficulties in mining and selection of the clay have probably caused the higher quartz contents noticed in recent years.

On the other hand, it is necessary to point out that quartz may be intentionally added to clay so as to produce the semi-silica or siliceous type of refractory, also that certain natural mixtures of clay and quartz exist which are used for the manufacture of similar products.

The full mechanism of the behaviour of quartz in such materials is not yet known, but, as suggested later in the Paper, some of our results indicate that there may be a difference, possibly only in degree, between natural and synthetic mixtures of clay and quartz.

Before proceeding further, some definition is necessary of what is meant by the term "quartz." In this Paper it refers only to particles of quartz which are visible in a microscope with a total magnification of about × 100. Smaller particles of silica such as may occur in normal fireclays, and which can be detected by X-rays, are not being considered specifically here.

TABLE 1.—*Quartz in Fireclay Squares, Shapes, &c. Received at Beckton* 1944-1945.

Source	Percentage of quartz. Each figure refers to a delivery of 10 to 40 tons
1 ...	5 3 4 3 3 3 4 4 5 3 19 5 10 5 8 7 3 5
2 ...	4 3 3 3 6 3 6 3 4 3 2 3 3 10 3 3 2 6 4 8 3 4 6 5
3 ...	11 11 5 8 6 5 10 9 10 4 14 12 12 14 15 9 7 8 12 10
4 ...	9 12 6 9 9 9 12 8 18 10 11 10 14 24
5 ...	6 4 4 8 5 6 8 6 6
6 ...	7 7 30 40 15

Resumé of Previous Work

This is only a short list of references; further information can be obtained with the help of the excellent catalogue of papers given in Chester's "Steelplant Refractories."

Hyslop (*Trans. Cer. Soc.*, 1925, **24,** 403) detected mullite in clay fired about 1,000°C. Ennos and Scott (*Mem. Geol. Survey of Fireclays*, 1925, No. 28, 3) reported acicular crystals in the glassy matrix of fireclays fired to temperatures exceeding 1,100°C. Schwarz and Merck (*Zeit. Anorgan. Chem.*, 1926, **156,** 1) discussed the solubility of quartz in the matrix of fireclay and its influence on the crystallization of mullite. A. T. Green (*Trans. Inst. Chem. Eng.*, 1927, **5,** 192) stated that quartzitic material may go into solution during vitrification and remain in that state after cooling.

Geller (*Tech. Papers. Bur. of Standards*, 1924, No. 279) reported extensive mullite formation accompanied by the conversion of quartz to cristobalite at 1,400°C. and 1,450°C., but Chester (*loc. cit.*) stated that cristobalite, appearing first at 1,100°C., is formed chiefly from free silica derived from dissociated clay and not from the quartz present, and that at higher temperatures the cristobalite tends to disappear with the production of glass; and that whilst the formation of mullite is complete at 1,100°C. the size of the crystal but not the quantity is influenced by further treatment.

Shelton (*J.Am. Cer. Soc.*, 1935, **18,** 289) noted the development of a vesicular structure on heating clay—quartz mixtures, accompanied by the crystallization of mullite and the solution of quartz in clay glass below 1,200°C.

Shelton and Meyer (*J. Am. Cer. Soc.*, 1938, **21,** 371) observed indications of the solution of quartz in clay glass.

Methods of Examination

Heat Treatment

Test pieces, each 1 in. cube, were cut and subjected to heat treatment in a muffle furnace at various temperatures for various times up to 28 days. Instead of a muffle furnace a gas-heated concentric furnace was used for the tests carried out at 1,400°C.

Refractoriness

The 1 in. cube test piece mentioned above was chosen because it is the standard size for the G.L.C.C. refractoriness test described in detail in Appendix 1 and used in this investigation for the assessment of refractoriness.

Thin Sections

Thin sections were prepared at all stages of the heat treatment and were examined microscopically, using generally a 25 mm. objective. Higher powers were used when necessary, in particular for the detection of very small crystals of mullite. From observation of the thin sections the proportions of quartz, clay, cavities, cristobalite, and glass were assessed by the method of linear intercepts. The proportion of mullite could not be determined in this manner: it is included in the glass. Similarly, macroscopic particles, generally of quartz, present in some of the materials examined had to be ignored.

Refractive Index

The technique described by P. F. F. Clephane (*Gas Journal*, 1942, **239,** 282) was used for the determination of refractive index range and mean refractive index.

Resistance to Thermal Shock

A furnace was designed in which a surface (4½ in. × 3 in.) of a test brick could be uniformly heated to 1,040° to 1,080°C. The temperature was maintained for 30 min., and the test piece was then withdrawn and allowed to cool to atmospheric temperature. The cycle of operations was repeated at discretion.

Material "A"

This material was derived from the Stourbridge area and, as far as the clay was concerned, it was typical of the products of that area. It was abnormal, however, in its very high content of quartz.

The proportion of quartz was greatly reduced by heating for seven days at 1,100°C., and further diminished by another seven days heating: thereafter the reaction became so slow that no further change was noticed after 28 days. The proportion of cavities increased while the quartz was disappearing, but afterwards decreased slightly.

At 1,200°C. the quartz was reduced in seven days to less than that remaining at the end of 28 days at 1,100°C.: there was but little further reduction even after heating for 28 days. The proportion of cavities developed was considerably higher than at 1,100°C. and continued to increase up to 14 days, after which it diminished.

Glass became an appreciable constituent after heating for 28 days at 1,200°C., and after 2 hr. at 1,400°C. mullite crystals were noticed in the glass areas at all stages.

The results of the tests are given in Table 2, and are shown graphically in Fig. 1. Photomicrographs of two of the sections form Plates 1 and 2, and a series of photomicrographs illustrating the disappearance of quartz are given in Plates 3a

* Paper presented to the Institution of Gas Engineers—Communication No. 305.

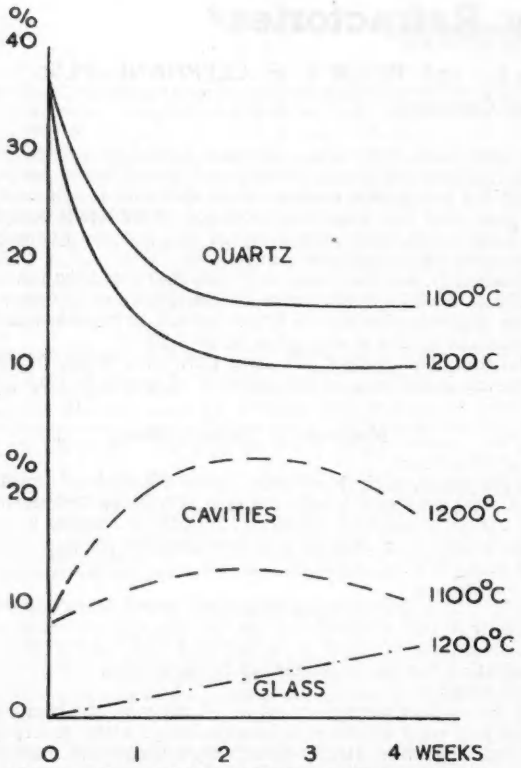


FIG. 1.—*Changes in Material " A " at* 1,100° *and* 1,200°*C.*

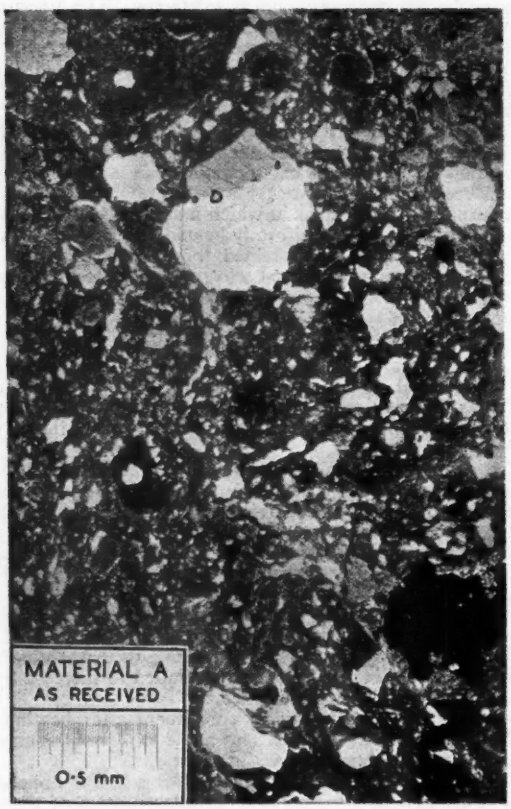


PLATE 1.—*Material " A " as Received*

PLATE 2.—*Material " A " after* 4 *weeks at* 1,200°*C., and* 2 *hr. at* 1,400° *C.*

PLATE 3A.—*Material " A " as Received*

PLATE 3B.—*Material " A " after* 1 *week at* 1,100°*C.*

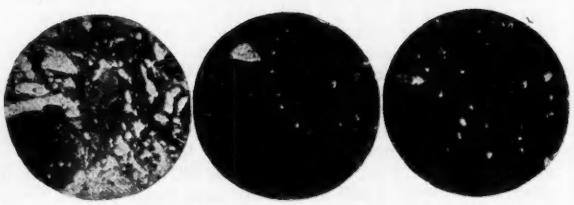


PLATE 3C.—*Material " A " after* 4 *weeks at* 1,100°*C.*

PLATE 3D.—*Material " A " after* 1 *week at* 1,200°*C.*

to 3e. A note on the interpretation of such photographs forms the subject matter of Appendix 2.

TABLE 2.—*Heat Treatment of Material "A."*

Temperature	Duration (days)	Quartz (%)	Glass (%)	Cavities (%)
As received	—	37	0	9
At 1,100°C.	7	21	2	11
	14	16	0	14
	28	16	1	11
At 1,200°C.	7	12	2	20
	14	12	2	24
	28	10	7	20
At 1,100°C. for time specified, followed by 2 hr. at 1,400°C. ...	7	6	4	18
	14	6	8	16
	28	6	8	20
At 1,200°C. for time specified, followed by 2 hr. at 1,400°C.	7	6	7	20
	14	6	6	26
	28	4	16	26
At 1,400°C.	2 (hr.)	12	4	22

TABLE 3.—*Refractive Indices of Material "A"*

Heat treatment	Duration	Refractive indices Range	Mean
A received		1.562 to 1.550	1.560
At 1,100°C.	7 days	1.555 to 1.510	1.539
	14 days	1.561 to 1.500	1.546
	28 dyas	1.555 to 1.510	1.539
At 1,200°C.	7 days	1.562 to 1.520	1.546
	14 days	1.567 to 1.510	1.548
	28 days	1.561 to 1.510	1.542
At 1,400°C.	2 hr.	1.558 to 1.500	1.544
At 1,100°C. for time specified, followed by 2 hr. at 1,400°C.	7 days	1.556 to 1.500	1.534
	14 days	1.561 to 1.500	1.535
	28 days	1.562 to 1.500	1.534
At 1,200°C. for time specified, followed by 2 hr. at 1,400°C. ...	7 days	1.555 to 1.520	1.532
	14 days	1.552 to 1.500	1.531
	28 days	1.555 to 1.500	1.528

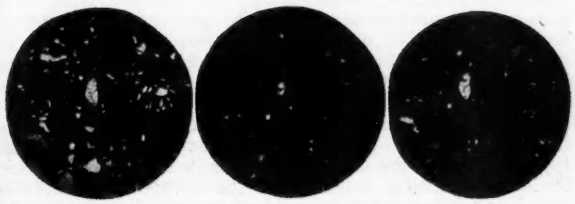


PLATE 3E.—*Material "A" after 4 weeks at 1,200°C.*

The shrinkage of the specimen in the standard refractoriness test was somewhat reduced by previous heat treatment (Fig. 2); the residual quartz was approximately halved by the heat treatment of this test (2 hr. at 1,400°C.). The proportion of cavities in the final product showed a slight reduction in samples pre-fired at 1,100°C. and a slight increase in those pre-fired at 1,200°C.

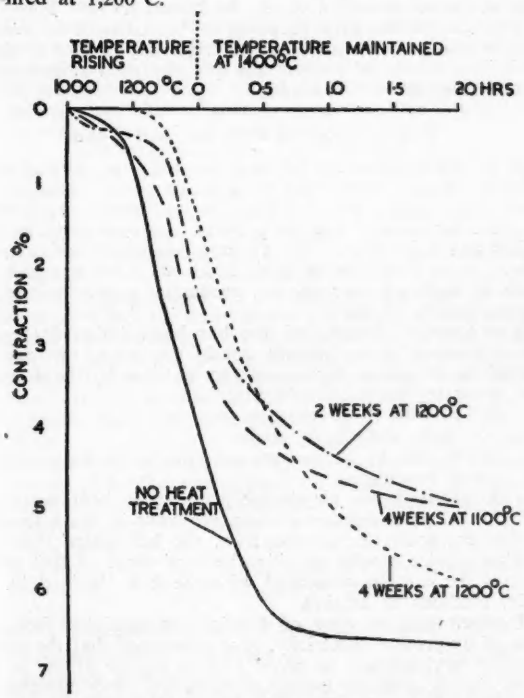


FIG. 2.—*Effect of Heat Treatment on Refractoriness of Material "A"*

It was noticeable that while mullite was present in the glassy areas after 2 hr. at 1,400°C., the size of the crystals and the quantity were markedly greater in those specimens which had been pre-fired at 1,200°C. for 28 days.

A study of the refractive indices shows that there was a marked reduction coincident with the disappearance of the quartz. (Table 3.).

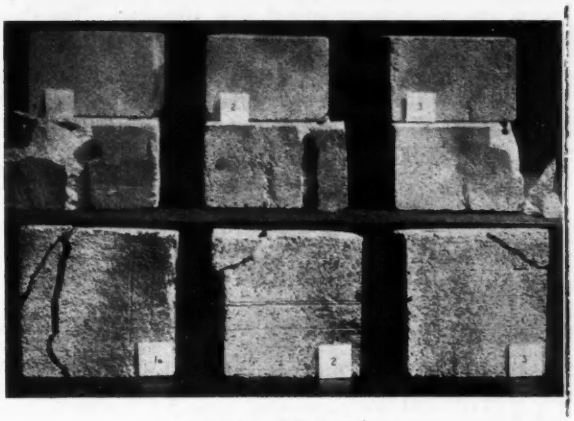


PLATE 4A.—*Material "A"*

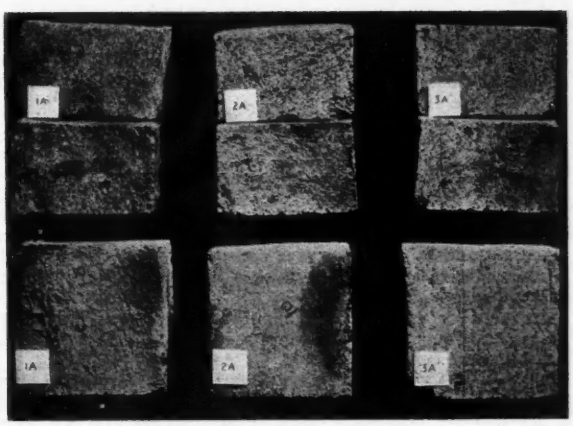


PLATE 4B.—*Normal Fireclay*

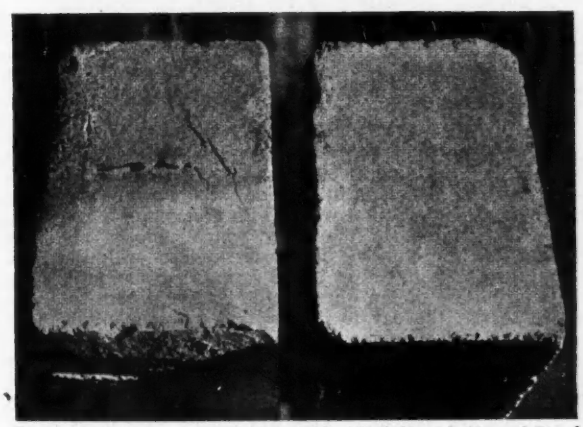


PLATE 4C.—*Comparison of Material "A" (left) with Normal Fireclay*

The resistance of the material to thermal shock was investigated by using three bricks cut into halves through the 3 in. × 4½ in. cross-section and subjecting the face thus formed to cycles of heating and cooling in the furnace described in Section III. In each case cracks developed during the first

cycle. During the second cycle the cracks extended and the surface showed signs of flow: some of the fine pores had closed, small protuberances had developed, and there was a general glazing. At the end of the third cycle the heated ends of the specimens disintegrated under slight finger pressure. For comparison purposes some normal fireclay was subjected to the same test: no change was noted in any of the three specimens after three cycles, one cracked after six cycles, and one was unchanged after 10 cycles. The third was not submitted to more than three cycles.

An original face of one of the high quartz bricks was treated in this test and the results were similar to those recorded for the cut faces.

Photographs showing the results of these tests form Plates 4a to 4c.

Twenty-eight test pieces, subjected to the I.G.E. permanent linear change test (2 hr. at 1,410°C.), showed contractions varying from 0·58% to 3·39%, the average value being 2·15%.

The analysis of this material was:—

	%
SiO_2	68·1
Al_2O_3	26·0
Fe_2O_3	3·3
TiO_2	0·9
CaO	0·4
MgO	0·4
Alkalis	0·8

(To be continued)

District Heating—The Wythenshawe Scheme*

By R. NICHOLAS, B.Sc., M.Inst.C.E.

City Surveyor, Manchester

WYTHENSHAWE comprises some 5,567 acres of land added to the City of Manchester in 1930. It has been planned to accommodate 80,000 people, its present population being 40,000.

The district heating scheme can, therefore, be applied to about one half of the total development together with two of the three industrial areas—one being already partially developed on the traditional method of individual space heating—and the civic centre.

The total area to be served is 1,310 acres.

The scheme is thermal-electric comprising two power stations located in the western and south-eastern industrial zones, servicing, by inter-connected mains, the intervening residential areas and civic centre as well as all the adjoining industrial undertakings. This dual power arrangement provides a stand-by or alternative source of supply to all parts of the scheme, as well as a more effective distribution in the two industrial areas.

Each boiler plant is designed for the generation of high pressure steam, being of water tube type and equipped with economizers, superheaters and air pre-heaters.

By use of mechanical stokers and an electrostatic precipitator, up to 98% of any grits or fines carried over in the flue gases will be removed, resulting in as clean a chimney emission as anywhere in the country at the present day. Coal will be serviced from railway sidings and elevated to high level bunkers, gravitating to the stokers as required.

The Heat Distribution System

Heat distribution to the dwellings and other buildings will be by hot water circulated by pumps located in the plant houses and in a number of sub-stations.

Twin trunk mains connect the two boiler houses, and branches from these connect to the sub-stations, from each of which a three pipe system conveys water to the buildings to be heated. This system provides separate flow pipes for heating and domestic hot water, with a common return pipe.

The temperature of the water which supplies both the heating and the domestic hot water systems will be varied by means of mixing valves in the various sub-stations. Thus the temperature of the water in the heating system could be varied to suit the day to day heating requirements without interfering with the temperature of the domestic hot water.

It should be pointed out that the heating system has been designed as a closed circuit, that is to say, once it has been filled, the water remains in the pipes, and is circulated round and round the system. This will enable steel pipes to be used, as corrosion or deposition on the pipe surface will be avoided.

The heating installations in the houses and flats will be of the conventional type in which the heat is emitted to the rooms by means of radiators and any exposed pipes. The greater part of the heat is to be provided by radiators and each will be fitted with a valve so that it may be turned "on" or "off" by the householder as desired. In general, installations in the houses and flats will, on the score of neatness, be designed on the single pipe system.

Each house will be equipped with its own separate domestic hot water system. This system will be of the conventional type except that the usual back boiler is dispensed with and, in lieu, a calorifier fitted inside the normal cylinder. The calorifier will be in the form of a copper coil through which the hot water from the district heating mains circulates and imparts its heat content to the surrounding water in the cylinder. The water passing through the coil is then returned to the district heating system for re-heating and re-use.

The scheme provides for the cylinder in each dwelling to be large enough to store 40 gall. of hot water so that, after overnight heating up, this amount of hot water will be available first thing in the morning. It is proposed that the water should normally be heated to 130° F.

The scheme has been prepared on the basis of an average consumption of 45 gall. of hot water per day in each dwelling. This is in excess of the average quantity used at present by the Wythenshawe householder.

Comparison of Service and Costs

It is estimated, from surveys carried out amongst the tenants on the estate, that the average cost of heating and hot water supply per dwelling by traditional methods is 6s. 11d. per week, based on pre-war fuel consumptions, and prices ruling in 1945. The average fuel consumptions were found to be five tons of coal, 2,000 cu. ft. of gas and 130 units of electricity per annum, producing approximately 278 useful therms of heat.

The District Heating scheme has been designed to meet the following space heating conditions, over an average period of 35 weeks per annum, in addition to the domestic hot water service previously described:—

60° F. with 1½ air changes per hour in the living room, parlour and dining room.

55° F. with 1½ air changes per hour in the hall, staircase and landing.

50° F. with one air change per hour in bedrooms.

55° F. with one air change per hour in the kitchen.

The bathroom is warmed from the hot water system.

This service would provide the equivalent of 761 useful therms per annum compared with the 278 obtained by the older methods of heating.

Furthermore, in view of the income available from the sale of by-product electricity, it is considered that the district heating service could be provided at a charge of 5s. 1d. per week to the average dwelling, based on 1945 construction and operating costs. This charge would vary from approxi-

* Paper to the Conference "Fuel and the Future" organized by the Ministry of Fuel and Power.

mately 1s. 9½d. per week for a single person flat, to 7s. 1d. per week for a four-bedroomed parlour-type house.

This average charge of 5s. 1d. per week for a district heating service compares with the estimated cost of 6s. 11d. per week for heating and hot water supply by traditional methods, it is considered that the difference of 1s. 10d. per week is ample to cover the cost of any supplementary heating in the form of gas or electric fires which may be desired.

In a large scale district heating and generating scheme it is not strictly economical to instal the heating and generating plant until a substantial number of houses have been erected and occupied. In such cases there must be an initial loss of from about £45,000 to £55,000 which can be reduced to the lower figure in a development programme of about 2,000 houses per year, when the commencement of plant operation is timed to coincide with the completion of the first 2,000 houses.

In the meantime it is more economical to provide these houses with immersion heaters, and a supply of electricity sufficient to heat 17 gall. of water per day during the seven colder months, than to accelerate the earlier capital charges on a plant working to small capacity.

To recover the initial loss of £45,000 over the subsequent ten years would mean an additional weekly charge per house of about 2d. per week, and a proportionate charge on public buildings.

Generation of By-product Electricity

The greater part of the electricity used in this country is produced in power stations in which steam is the motive power and the electricity generation is effected in turbo-alternator sets. The steam is fed at high pressure to the turbo-alternators which extract energy from it and convert this energy into electricity. As a result of this conversion the steam, when it reaches the turbine exhaust, has been lowered in pressure and temperature. It still, however, contains its latent heat, which is dissipated by means of cooling towers or in warming the water of a nearby river. This wasted heat often amounts to upwards of two thirds of the total heat in the steam and, consequently, even the largest generating stations in the country have an overall thermal efficiency of only about 30%.

It is this latent heat in the exhaust steam which it is proposed to use in the Wythenshawe scheme, to heat the water for circulation in the district heating service.

With this arrangement the only fuel which is required for generating the electricity is the additional amount necessary to put into the steam the work-producing energy absorbed in the turbines and converted into electricity. After allowing for boiler and all other losses, the overall efficiency of converting this heat into electricity is in the region of 75%, that is about two and a half times the overall efficiency of a modern electricity generating station of the usual type in which the exhaust heat is wasted.

The great advantage of by-product electricity production from a combined thermal-electric generating station serving a district such as Wythenshawe is, that the maximum output of electricity would be available at the time of year when it is most required. The amount of electricity produced would vary according to the outside temperature and the resulting load on the district heating system; this means that most electricity would be available during the months of December, January and February, and it is during these cold months that the peak annual demand for electricity occurs.

In the case of the Wythenshawe scheme, where water is the heating medium, the very large heat storage capacity of the water can be used to enable the turbines to be run up to maximum load for short periods.

The installation of by-product electricity generating plant in addition to that required for a straight heating station, involves only the expenditure of a fraction of the capital which would otherwise be necessary to instal plant of similar capacity in the usual type of condensing station.

It is estimated that the saving in fuel at Wythenshawe by the combination of thermal and electric generation would amount to 22,000 tons of coal per annum.

Estimated Capital and Operating Costs

The amount of electricity which can be generated under the scheme is estimated at over 75,000,000 units per annum and the generator output during the half hour peaks of the period of annual maximum demand will be 31,300 kW. The wholesale value of this electricity is in the region of £169,000 per annum.

The capital cost of the whole Wythenshawe district heating scheme, based on prices ruling in 1945, is estimated at £2,427,000.

This is made up as follows:

	£
Land	8,400
Building work in boiler houses, sub-stations, sidings, &c.	265,490
Plant	1,255,402
Mains in trunk and secondary distribution	528,345
Ducts for distribution mains	369,220
Total	£2,426,857

The annual operating costs have been estimated as follows:—

	£
Annual charges on capital cost	151,905
Maintenance and administration	40,422
Labour	16,550
Coal	136,310
Ash removal, water, &c.	1,786
Losses due to empty houses, &c.	641
Rates	31,549
Total annual expenditure	£379,163

Income:—

	£
7,945 dwellings at an average charge of 5s. 1d. per week	107,209
Public buildings (i.e., Civic Buildings, Churches, Cinemas, Public Houses, &c.)	43,550
Industrial Buildings:—	
Heating	43,166
Process Steam	17,828
Sales of electricity	168,601
Total income	£380,354

Summary of Advantages to Wythenshawe

Advantages to Householders.

(*a*) A district heating service will provide a constant supply of hot water day and night.

(*b*) It will provide a degree of warmth and comfort hitherto unknown, and within the range of the average householder's pocket.

(*c*) It will warm not only the rooms, but the hall, staircase and landing, and so prevent cold draughts when the room doors are opened and shut.

(*d*) It will enable the occupiers of the larger houses to obtain, during the winter, the full benefits of the size of the houses, as they cease to be restricted to the use of only one or two rooms because of heating difficulties.

(*e*) The living rooms and kitchen will be warm when the family comes downstairs in the morning.

(*f*) The buildings will be kept dry and free from damp. This feature is specially advantageous in the Manchester area due to local climatic conditions.

(*g*) In case of sickness, an even warmth can be maintained in the bedroom without the emission of dirt or adding to the labours of nursing.

(*h*) Clothes and household linen can be kept fully aired.

(*i*) There will always be a hot pipe in the bathroom for drying towels.

(*j*) The heating of the hot water in the summer months will be effected without the discomfort of having a fire or sectional boiler in the kitchen or living room.

(*k*) It will obviate the worry to the householder of having to leave a fire alight and banked up when he goes out.

(*l*) It will be labour saving.

(*m*) It will be cleaner; there will be less dust.

(*n*) It will be safe—particularly to young children.

(*o*) It will increase the available floor space due to the omission of a number of fireplaces and chimney breasts.

(*p*) It will minimize trouble from burst pipes in frosty weather.

(*q*) It will avoid carting through the estate thousands of tons of coal and ashes, the dust and grit from which would be scattered while handling into and out of consumers' premises.

The smoke nuisance is particularly serious in Manchester. Its effects are aggravated because the hills which surround the city on three sides encourage the condensation of moisture in the atmosphere.

The advantages which the citizen will obtain from the installation of a district heating system at Wythenshawe would accrue chiefly from the resultant reduction in smoke emission from domestic and industrial chimneys in the area. This aspect is particularly important in view of the proximity to the estate of the Corporation's Sanatorium at Baguley, and the Ringway Airport.

The ratepayers will obtain the monetary benefit resulting from a lesser expenditure on the upkeep of the property. Clean air in Wythenshawe will mean a considerable saving in respect of decoration and general structural maintenance. There will also be a considerable annual saving to the ratepayer in the cost of heating public buildings. This saving is estimated at £14,500 per annum.

As regards the adoption of a large-scale district heating scheme, Wythenshawe has a particular advantage in that approximately half the estate consists of houses already developed, but heated by traditional methods, and comparable in size with those projected. This affords a freedom of choice for the resident which enables a direct comparison to be made between the two methods of heating.

Corrosion of Gas Appliances

Discussion on the Paper by N. Booth and P. C. Davidge (Gas Reseach Board) and G. H. Fudge and B. Pleasance (South Metropolitan Gas Company. The Paper was published in the "JOURNAL" of December 11 and December 18

MR. **Arthur Forshaw**: As Chairman of the Utilization Committee of the Gas Research Board I am privileged to open the discussion. It is the first of what we hope will be a series dealing with corrosion in gas appliances, and some idea of the factors other than those dealt with here is given. In fact the present Paper, although its subject has provided an important part of the Committee's work, is really only a progress report of what we have, so far, been able to carry out.

It is important that we should understand clearly what is the problem, and I would like to restate it now. Water heaters of the type dealt with, if we exclude "improper use," require maintenance, made necessary by the action of corrosive elements in coal gas and by the deposition of corrosion products. The parallel programme of the Board consists in the attempted removal of the residual organic sulphur compounds in the gas. We felt that it was important to know just how these sulphur compounds were affecting water heaters, and whether their removal, in whole or in part, would improve the position as regards maintenance charges. It was realized that if maintenance costs could be materially reduced, this would offset the cost of sulphur removal. It now appears from the results of these investigations that, from this point of view, for present forms of heater a minimum sulphur content (in the neighbourhood of 3 gr. per 100 cu.ft.) exists, below which it would be undesirable to purify coal gas. For the moment then, this is the most important single point established by the work.

Questions Needing Study

We must continue this work until we have a complete picture of the practical limitations in the case of existing heaters, including establishing the optimum point to which sulphur removal should be carried. The next step will then be to dissect the problem and examine theoretically the possible effect of changes in design and construction. We must, for example, study combustion, heat transfer, and the protection of metal surfaces which are corroded under the conditions of use. We have indications in this Paper that tin-lead protective coatings are by no means entirely satisfactory, and other metals and alloys must be examined to find a coating which is less permeable to copper than tin, and more adherent than lead. From the point of view of heat transfer, we already know that most of the work in these appliances is done by the fins. We should know whether we are imposing too high a strain on these, or whether we could alter the conditions of combustion and/or heat transfer to give the same efficiency of performance, which, as you know, is already very high. When we have done this, we may be able to define more exactly the limitations which design and construction place upon performance and rating.

It appears to me that the investigations, in addition to helping the gas production side of the Industry by confirming that reduction of sulphur to something in the neighbourhood of 3 gr. is more useful than the more difficult and presumably more expensive complete elimination, also furnishes the technical departments of the appliance makers with data, obtained under definite conditions of use, that are not only important but, so far as I know, not otherwise available in published form. It would be invidious of me if in my privileged position I were to comment on this data, or on the Paper generally, at any length and so possibly forestall those who wish to take part in the discussion. I will, therefore, content myself with observing that the results of the reduced consumption tests provide food for thought in their unexpectedness. Makers have usually preferred to recommend a slightly reduced input to guard against the opposite—that is, an input greater than the maximum for which the appliance is designed. Practical results show that this latter makes for rapid increase in the fluffy deposits and that these in time soon cause the excellent original CO/CO_2 ratio of the finned type of heater to approach the standard limit. It may be that just as this investigation is pointing to a very narrow optimum range of sulphur content in the gas, it is also indicating a rather narrow optimum range of consumption from the point of view of corrosion effects.

Possibly the Committee will have to give some attention to this aspect of the problem and add the determination of the CO/CO_2 ratio to the other data. Finally, I am inclined to the opinion that the method of test adopted is rather more severe in its effects than would be the case with a similar number of heatings in domestic service where residual heat often prevents initial condensation. The correctness or otherwise of this opinion would not, of course, affect the findings of the investigation except in the number of heatings without servicing to be expected in domestic use which would be increased if the opinion is well founded.

Dr. **H. Hartley** (Radiation Ltd.): This factual report carries a stage further and confirms the earlier investigations of Wood and his coworkers with materials for water heaters used under non-condensing conditions. The results have not such a wide application as those recorded by the earlier workers but, being made with actual heaters, are, no doubt, of more immediate interest to the utilization staffs of undertakings.

In the "non-condensing" heater there always results some formation of condensate during the initial heating up period. The extent to which such a deposit is formed and the rate of its evaporation are of first importance. As formed, the condensate is dilute, but before removal concentrated sulphuric acid is produced, and it is during this concentration that the material of the combustion chamber may suffer. The collection of free sulphuric acid on the surface of the appliance is often masked by the products of corrosion. When appliances are made of non-corrodible materials, the surfaces may become coated, after prolonged use, with a sticky liquid rich in sulphuric acid. The formation of this substance can be noted in water heaters made of corrosion-resisting materials, and in the interior of gas ovens coated with acid resisting enamels. In all appliances it is desirable, if economic, to use materials which are resistant to the action of sulphuric acid, and the fact that free sulphuric acid may be found in noticeable quantities provides some testimony to the resistance of the materials used.

Nickel-chromium-molybdenum steel can be used for the combustion chambers of water heaters in such a way as to minimize corrosion. Alternatively, satisfactory results are attainable with cement asbestos compounds, although the range of application of this latter material is somewhat more limited.

Consideration of the conditions under which deposition of liquid takes place leads to an appreciation of the significance of the dew point of the flue gases. The report refers to the fact that the dew point is lower when the proportion of sulphur oxides is lower, so that the amount of condensation may be lessened either (*a*) by allowing excess of air to flow through the combustion chamber, (*b*) by ensuring that the sides of the combustion chamber are maintained hot, (*c*) by eliminating sulphur.

A Critical Factor

The dew point is critical and in designing apparatus for intermittent use, the details have to be adjusted to ensure that the period of time during which deposition can take place is kept to a minimum. This is the case even when the material used for construction is of a composition highly resistant to the attack of the acids—it is even more important if there has to be reliance on a protective coating, which itself may not be completely continuous or impervious to acid.

Before new water heaters are marketed, it is our practice to arrange for them to be tested up and down the country over a considerable period of time. It has been my experience with appliances made of copper, protected by coatings of lead-tin alloys, that for the first few months good results may be obtained, but subsequently deterioration sets in at an increasing rate. If the Industry is to attain real success with the water heating load, arrangements must be made either to supply a gas which will give products which are less corrosive, or to use appliances made of corrosion-resisting materials.

There are some details of the work described in the Paper which might have been expanded with advantage. It would have been informative if CO/CO_2 determinations had been made at the beginning, during, and at the end of each period of test. These would have provided not only an indication of any deterioration in the combustion but also of such changes in the concentration of the flue gases as were taking place. More frequent tests of the CO/CO_2 content could have been used as an index of dilution, and so of the SO_2 and SO_3 content and of the dew point. The actual determination of the dew point also would have been of interest.

Towards the end of the report there is a suggestion that a solder coating had been used on the water faces of the heater. It is not good practice to use a lead-tin alloy if there is any possibility of the liquid being used for drinking purposes. The coating should be of tin.

Fostering Greater Understanding

Mr. **H. Stanier** (Chief Chemist, South Metropolitan Gas Company): The joint effort characterizing this Paper is an example of a type of co-operation between the Gas Research Board and member undertakings which I think we should all like to see more widely extended. The establishment of such close contacts between the research workers of the Board and their industrial counterparts can do much to foster a better understanding of problems to be investigated and greatly help to promote the application of the results of research throughout the Industry. For our part, we in the South Metropolitan Gas Company have welcomed this collaboration and are much indebted to the Director of the Gas Research Board for making it possible; it has been a case of real teamwork and I am sure that all those taking part have profited from the experience.

One of the most important findings in the Report, which confirms some earlier observations made in our laboratories, is that the amount of corrosion occurring in instantaneous water heaters is roughly proportional to the sulphur content of the gas, although it now appears that there is a limiting sulphur concentration, possibly in the neighbourhood of 3 gr. per 100 cu.ft., below which this generalization no longer holds. This information enables us for the first time to form some estimate of the possible savings in the maintenance of these appliances consequent upon any particular reduction in the sulphur content of the gas. For example, if one takes a normal straight coal gas or containing on an average about 30 gr. of sulphur per 100 cu.ft., a reduction to 15 gr. should cut servicing charges roughly by one half; at 10 gr. the charges would be approximately one-third and at 3 gr. only about one tenth. Clearly the full advantage of a trouble free appliance cannot be achieved unless the sulphur in the gas is reduced as nearly as possible to the 3 gr. limit, and this should be borne in mind when considering the installation of any process of sulphur removal which adds materially to the cost of the gas.

Must Reduce Sulphur Content

This brings me to the recommendations made in 1942 by the Institution Committee of Enquiry on Sulphur Removal and to the proposal of the Heyworth Committee for a statutory limitation of the sulphur content of gas to a maximum of 10 gr. per 100 cu.ft. With a gas containing about 30 gr. of sulphur, it is possible by the normal oil washing process for benzole recovery to reduce the sulphur content to about 15 gr. without adding to the cost of benzole extraction, so that a real saving in the maintenance of appliances can in this way be achieved without increasing expenditure. If, however, we have further to reduce the sulphur to 10 gr., normal oil washing will no longer be adequate and a more expensive process will be needed. For this extra expenditure all we are likely to achieve is a reduction of 33% in corrosion—an effect which would scarcely be noticed in appliance maintenance. I would submit, then, that if a statutory maximum for sulphur content is required it should be in the neighbourhood of 15 gr. rather than 10 gr. and that there are far stronger grounds for recommending that where possible the sulphur content should be reduced to about 3 gr.

Whether there would be any advantage in reducing the sulphur below 3 gr. is doubtful in view of the effect of nitric oxide at very low sulphur concentrations, but I think it worth noting that the corrosion deposits formed from this constituent of the waste gases are much more coherent than those produced from the oxides of sulphur; they would thus be less likely to cause trouble or inconvenience to the consumer.

A Matter of Great Concern

Mr. **Whitaker** (Ascot Gas Water Heaters, Ltd.): The effect of corrosion by combustion products on gas water heaters is obviously of very great concern to the designer and manufacturer of these appliances. So little factual information has been available in the past as to the causes of the attack and what can be done to improve the position, that I am exceedingly glad to see this description of the work done by Dr. Booth and his colleagues; further, I am exceedingly pleased to hear that this represents only the beginning of a more extended investigation. Factual information on the subject being so scarce, we are tempted to try and deduce from the data given in this Paper more, perhaps, than the Authors would care to suggest as any very sound foundation. There are certain rather peculiar features in the results, conclusions from which may or may not be justified from the figures available.

In the two types of heater which were investigated, the overall losses by corrosion were not very different although the composition of the coating in one case was 50-50 tin-lead, while in the other it was approximately 80 lead and 20 tin. The thickness of the two coatings in the two cases was in the ratio of approximately 10: 1. In view of the fact that corrosion has presumably in the early stages of the life of a water heater a surface rather than a film effect on the coating, you would not expect a very great variation between these two except that it had been felt that—since from the beginning of the corrosion of instantaneous gas water heaters the corrosion products contain copper—you only get corrosion products by the process of solid diffusion through the alloy layers formed on it. The probability—and one cannot put it very much higher—is that the diffusion of copper will be slower through the high lead-alloy layer than through the lead alloy containing a relatively high percentage of tin.

From the results given in this Paper, therefore, one would expect to see considerably higher copper losses in the case of the thin coating containing a high proportion of tin. Actually, the loss is higher, but not as much higher as one might have expected.

Metal Losses

There are one or two other small but rather peculiar trends in the figures. One of them is evident if you consider the losses of tin to lead in all cases. In all the examples given in the second, third and fourth consecutive periods—I leave out the first period of test because, as the Authors have pointed out, a certain amount of corrosion product is left on the surface of the heaters and therefore the amount of deposit at the end of the first period only may not be strictly comparable with the other periods—we have the effect that the loss of tin decreases during the three periods. Expressed as percentages of the total losses of tin in Periods 2, 3, and 4, are reduced in the order of 37, 34, and 29, whereas the loss of lead increases in the same proportion. It is difficult to explain this, and it may have significance.

Again comparing the loss of tin with the loss of lead, whereas there is considerable difference in the losses in heaters A and B, if the loss of tin is weighted and proportioned to its concentration in the coatings in the two cases, the losses are similar.

Effect of Dew Point

There is one point—and it comes nearly at the beginning of the Paper—on which I am not sure that the assumption made by the Authors can be completely justified. They assume that the bulk of the corrosion in instantaneous water heaters occurs during the initial heating up period from cold. The assumption is that when a heater is running continuously, most of the solid surface in contact with the combustion products will be at a temperature above the dew point of the combustion gases. But we do not really know what the dew point is. The dew point of water vapour alone is of the order of 150° C., under normal conditions. The dew point for sulphuric acid appears, according to the literature available, to be within a rather vague range of between 200° and 300° C. Where it actually falls in that range depends on many factors, some of which are very difficult to assess, particularly the rate at which the SO_2/SO_3 equilibrium is obtained, the effect of that equilibrium, the corrosion products already present, and their probable catalytic action on that reaction. We know that if the dew point is anywhere in the neighbourhood of 350° F., even under steady running conditions a considerable area is within the dew point range, and I think it would be valuable in future work if a comparison, at any rate in one or two instances, could be made of the extent of corrosion with intermittent and continuous running.

Undue Pessimism Shown

Mr. **J. E. Cooper** (Officer-in-Charge, Water Heating Laboratory, Watson House, Gas Light and Coke Company): The voluminous technical literature on the subject of corrosion with the exception of the work by Wood, is of little help in dealing with the problem of the so-called " non-condensing " gas-fired water heater. For some time we at Watson House have, naturally, been concerned with this particular problem and other similar ones, notably the protection of cast iron in larger appliances than those being considered to-day. This Communication has, therefore, been studied with interest. I would extend my personal sympathy to the Authors, as in my view the difficulties encountered in this work are exceeded only by its vital importance.

There are several points on which I disagree with the Authors, but I wish to make it plain that the criticisms are put forward in a constructive spirit.

The whole accent in this Communication is on the degree of attack on the fabric of the heating body, whereas from the safety point of view the degree of restriction of air for combustion by blockage of the spaces between the fins is the salient point. Thus I feel that determinations of carbon dioxide concentration in the flue gases as the tests proceeded would have yielded useful information. I agree with other speakers who have suggested the determination of CO/CO_2 ratios throughout. As a measure of the nuisance caused by the deposit, as distinct from the potential danger, determinations of bulk density of the corrosion product would have been well worth while.

I note the statement "Servicing is necessary every three to six months." This is surely unduly pessimistic, and may hand to our rivals a weapon to which they are not entitled.

It will be interesting to know if the Authors have noted any progress in corrosion with the heaters off. We have sometimes found that on re-starting life tests after having shut down for two or three days, there is evidence of some growth of the corrosion deposit, as evidenced by an increase in carbon dioxide content of the flue gases. Our investigations have not proceeded further than to note this occurrence. It is, of course, well known that cast iron is attacked when the appliance of which it forms a part is not working; hence the need to clean out central heating and central hot water boilers at the *end* of a heating season.

On heaters B_2 and B_4, which were run at 90% of normal heat input, the water temperature rises are lower than on those heaters which were run at normal rate. While agreeing that (*a*) it is likely that the bulk of the corrosion occurs during the heating up period, and that (*b*) on heaters B_2 and B_4 this period would, comparatively speaking, be protracted, the introduction of a further variable (lower outlet water temperature) has, in my opinion, completely clouded the issue.

As an aside on this point of heat input, I would say that in general manufacturers' ratings for particular heaters are unduly high, being apparently settled by the desire (not unnatural) to show as high an output as possible from a given appliance. But even if the rating is based on the combustion characteristics of the heater—*i.e.*, by determining a limiting rate and then dividing it by 2 (to accord with B.S. 717) the resultant "normal" rate will, according to our findings be too high if due consideration is to be given to the question of maintenance costs, which, on the instantaneous non-condensing types, consist to a high degree of time spent in dismantling for the purpose of cleaning.

Tin-Copper Compounds

No direct mention is made of the tin-copper compound in its various forms. It is our view that, particularly in tin-rich coatings such as those on the A series of heaters, these compounds play an extremely important part in the corrosion mechanism. There is evidence that these compounds are formed at an early stage in the life of the heater and that they possibly diffuse through the protective coating and thus present copper to attack before the coating is broken. Table 4 is interesting in this respect. The copper content of the deposit after Period 1 deserves study; it is significantly high, although it is possible that the dipping baths contained copper.

It is worth mentioning that on one sink heater patches of tin-copper compound have been noted before putting the heater into use, thus immediate attack could occur on the copper at these points.

Table 6 indicates the presence of carbon in the deposit from Heater A. If blockage proceeds sufficiently for carbon deposition to occur, excess air will have been so much reduced as to elevate the condensation temperature appreciably, thus leading to heavier attack, and to gross overheating of the protective coating by flame contact.

I consider that the work could have been much simplified by the use of plain copper heaters of simpler construction than those tested. For example, the difficulties of obtaining silhouettes of the B type heater are very great. The analytical work which has been done has been rendered laborious by the need to determine three metals and at least one acid radicle in each sample. I realize that the desire has been to examine the performance of actual heaters, but, as is known, these vary considerably in their performance; some of the reasons for these variations are, I feel, to be found in the photomicrographs.

In conclusion, I hope that this Communication will cause manufacturers to devote even more care to this problem than they have done in the past. I would stress particularly the need to arrange for the heat input to match the protective coating employed, and the necessity for finding a coating superior to those used at present. It is gratifying to note that at least two manufacturers have realized that "tin must go," and are supplying what they describe as pure lead coatings.

Influence of Alloy Layer

Mr. W. L. Hall (Liaison Department, British Non-Ferrous Metals Research Association): My reason for speaking is to draw attention to one metallurgical factor in the conclusion which Mr. Welsh draws from his metallographic examination in Appendix 3. In Conclusion 2 it is stated: "In unused heaters the protective coating is not alloyed with the copper walls, &c., and the layers for each heater wall are uniform in thickness and show neither porosity nor pinholes." I feel it is general to consider that under the conditions of dipping the coating on these heater bodies, and with the types of solder used, there would be an alloy layer present on the heater bodies before they are put into service. I think that if Mr. Welsh had used a somewhat higher magnification for the examination of his coatings—something of the order of 500—this alloy layer, which I think it is true to say is usually made up of two copper-tin phases, would have been visible. I wish to draw attention to this point in view of the statements that have been made this afternoon about the effect of these copper-tin compounds, and in view of the fact that this Paper is obviously just the commencement of a series of tests. Therefore, I think it is important to realize that the alloy layer, with solders of these compositions, will be there from the start. As indicated in the Paper, this alloy layer will grow in thickness as the heater is in service, and some published work on the effect of heating soldered joints on copper suggests that for different tin-lead ratios, different copper-tin phases become prominent in the coating, and I think these points might be borne in mind when further work is being considered to follow up that initiated by these tests.

Further Considerations on "Alloying"

Mr. J. Emerson (Main Water Heaters, Ltd.): The time periods of 3¾ minutes used in the test are excellent for giving a good degree of acceleration, and useful for getting comparative performances, but the results should not be expected to correlate too closely to practical performance as they tend to over-emphasize the effect of condensing conditions. The heater is cooled right down in the "off" periods, whereas in practice residual heat, combined with heat from the pilot, keeps the unit appreciably warm.

We are given to understand that alloying between the copper and the solder takes place while the heater is in use. Presumably this alloying is accelerated at higher temperatures, and therefore under practical conditions, where the fins seldom cool right down, will be carried on to a greater degree than under the test conditions. This results in greater corrodibility of the metal surface.

It is surprising that no alloying takes place in the coating process, especially in the type A heaters. Here, with the high percentage of tin, together with the fact that the solder was applied by wiping, one might have thought that alloying could hardly have been avoided. Can the Authors explain the formation of the alloy during use? Is there some threshold temperature such that we could avoid alloy formation by keeping the fins below that temperature? Do the Authors consider that a pure lead deposit, if practicable, would further delay corrosion, owing to the impossibility of solid solution of copper in the lead? It is significant that the type A heaters produced more deposit than the type B. How much of this difference can be ascribed to the difference in thickness of the two coatings, and how much to their different compositions?

With reference to the effect of lowering the rate of heat input, it might be expected that the rate of corrosion would be reduced if only on account of the lower concentration of sulphur oxides and water vapour. It is true that the condensing time is prolonged, but it is doubtful whether the total condensation is as great.

In any case we have evidence that the formation of deposit in a large finned heater was considerably reduced by a reduction of 5% in the thermal input. Conditions were admittedly different in that the time period was ½ hour on and ½ hour off. In addition the water rate was adjusted so that the outlet temperatures were the same in both cases. This is, in my opinion, an important point, as the amount of condensation is well known to depend appreciably upon the temperature of the water flowing through the heater.

Criticism in Good Part

Dr. R. Kerr (Chief Chemist, Ascot Gas Water Heaters, Ltd.): I hope the Authors will accept these criticisms of mine rather as suggestions for future work.

First, with regard to the protective coatings themselves, Heater A appears to have had only a thin coating of solder which was apparently applied by wiping before the heater was fabricated. The coating was of the order of, roughly, a ten-thousandth of an inch. Incidentally, I congratulate those who did the analysis and got it up to exactly 100%. In the case of Heater B, the analysis is incomplete, and it is rather a pity that the analyst had not time to find out what the other 2% was, as it is possible it might have had some effect on the corrosion. This coating was applied by dipping the assembled body into the solder bath and allowing it to drain. Of course, this produces a much thicker coating and also one in which the thickness is variable. The Authors give it as varying from 0.7 to 2.4 thousandths of an inch which is rather more than I should have expected, but it is still quite reasonable.

Like several previous speakers, I am very surprised to find there is no alloying with the solder on copper base, and in particular, coating A, which has a lot of tin and antimony. I should have expected to find signs of both the tin and the antimony alloying with the copper, for I have examined coatings of this type and found evidence of alloying in all but one instance. I am also astonished there were no signs of porosity on any of the coatings. I should be very surprised, particularly in the case of the coating one ten-thousandth inch thick, if there were no signs of porosity. I have had considerable experience of testing coatings and have found that to be free from porosity you must go to 10 times that thickness.

I also agree with the speaker who suggested that a higher magnification in the micro-examination would in all probability show alloying. Incidentally, in Plate 14 there seems to be some sort of layer between the solder and the copper base, and if that is not an alloy layer, I should like to know what it is.

In the coating on Heater B, the adhesion appears to be rather poor and there is some evidence of stripping. I do not know anything about the history of that heater but it is possible that the copper was

tough pitched copper instead of de-oxidized copper, owing to shortage of material, and that might account for the poor adhesion. It is a pity that the Authors did not examine the copper as well as the coatings, because that can have considerable influence on the results. In this respect it is quite likely that Heater B is not representative of the makers' current production, but one produced in times of difficulties with raw materials.

In regard to the tests themselves, I again agree with several speakers that it is unfortunate that no check was kept on the composition of the flue gases, particularly as the Authors seem to have checked the composition of the gas supply so carefully. I think it would have been very helpful if they could have determined the CO_2 and CO during running, and the SO_2 and SO_3 also. This information would have been very interesting in this particular case because the heaters used two entirely different burners. One has the Bray jet and the other the pinhole burner, and it would have been interesting to see whether this difference in the burners made any alteration to the SO_2/SO_3 ratio.

I should also like to know if the Authors made any determination of the nitrogen compounds in the low sulphur gas tests. Corrosion in the case of the low sulphur gas was apparently mainly due to the nitrogen compounds, and I should like to know whether this arose from the nitrogen of the air or from nitrogen present in the gas supply.

Like previous speakers, I am surprised at the comparatively small difference in corrosion with the two different types of coating, but there again I think that possibly the difference in the copper may have something to do with it. The poor adhesion of what should be a much more protective coating may cause the results to be less favourable. Also it is possible that the difference in the burner design may have had some slight effect on the result.

There is another point. It is with regard to the accelerated tests. When a heater is installed in a house it spends long periods of its time standing idle, usually in the kitchen where the air is saturated or even super-saturated. During that time the pilot jet is alight and the result is that a stream of super-saturated air passes through the heater. I think that may have some effect on corrosion, and it might be useful if the cycle could be modified to include something simulating these conditions. As it is, a heater standing in super-saturated air is completely missed out in these tests.

Liquor Effluents and Ammonia Committee

THE following is the 8th Report of the Liquor Effluents and Ammonia Committee of the Institution of Gas Engineers, presented at the Autumn Research Meeting of the Institution on Nov. 26.

The members of the Committee are:

Charles F. Botley (Chairman); T. Lewis Bailey, Ph.D.; H. T. Calvert, M.B.E., D.Sc., Ph.D.; W. A. Damon, B.Sc.; E. V. Evans, O.B.E., D.Sc.; H. Hollings, D.Sc.; P. G. G. Moon, O.B.E.; A. Parker, D.Sc., C.B.E.; P. Parrish; E. W. Smith, C.B.E., D.Sc.; B. A. Southgate, D.Sc., Ph.D.; A. H. Eastwood, E.Sc., Ph.D. (Research Chemist); Prof. John W. Cobb, C.B.E., D.Sc. (Honorary Secretary).

Ex officio: The President, the two Vice-Presidents, and the Honorary Secretary of the Institution.

Co-opted: Leslie F. Stemp, B.A., LL.B.

It is now nearly nine years since the Committee submitted to the Council of the Institution its 7th Report, which was presented and discussed* at the 9th Autumn Research Meeting on Nov. 3, 1937.

The subsequent activities of the Committee have been recorded briefly as part of the 4th and 5th Reports of the Research Executive Committee, and, since 1940, in the annual Report of the Chairmen's Technical Committee. The Liquor Effluents and Ammonia Committee considers, however, that the time is appropriate for the presentation to the Council, in a separate Report, of a short statement of its work, and of the methods at present regarded as the most suitable for the utilization and disposal of gas-works effluents.

General Activities

From 1926 to 1937, investigations into the production of ammoniacal liquor during the manufacture of gas, the utilization of the ammonia contained in it, and the disposal of crude and waste liquors were carried out at Hinckley and, later, at Coventry and Leamington, where facilities and assistance were kindly provided by the Authorities concerned. It was stated by the Chairman, in presenting the 7th Report of the Committee, that a stage had then been reached when the knowledge acquired could be utilized with practical advantage and that the Council, in view of other important problems calling for investigation, had decided to suspend, for the time being, the research activities of the Committee.

In order to collect together and make readily available to the Gas Industry the results of the work up to that date, the Committee arranged for the preparation by its Research Chemist, Dr. Arthur Key, of a Manual which was published by the Institution, in November, 1938, under the title "Gas-works Effluents and Ammonia."† This book has been widely used by the Industry, and copies are still obtainable from the Secretary of the Institution.

When, in 1939, the research work of the Institution was entrusted to the newly formed Gas Research Board, the Research Staff of the Institution was also transferred to the Gas Research Board. The Liquor Effluents and Ammonia Committee has, however, actively continued its work of reviewing the effluent problems of the Industry, and the Committee has, indeed, on many occasions been able, from its wide experience, to assist and advise gas undertakings which were faced with problems relating to effluent disposal. The services of Dr. Key and, after his resignation, of Dr. A. H. Eastwood, have continued to be available to the Committee through the courtesy of the Gas Research Board.

During the recent war years, when the maximum recovery of ammonia has been a matter of national importance, the Committee has assisted by making available to gas undertakings a confidential report, prepared by one of its members (Mr. P. Parrish, M.Inst.Gas E., F.R.I.C., M.I.Chem.E.) entitled "Manufacture of Concentrated Gas Liquor (15%) at Small and Medium-sized Gas-works under Emergency Conditions." It also arranged, at the request of the Ministry of Supply, for the preparation by Dr. A. Key of a Memorandum on "The Operation of Gas-works Plant to Secure the Maximum Recovery of Ammonia and the Production of a Strong Ammoniacal Liquor," which was circulated with the approval of the Council, to all gas undertakings in March, 1942. On other matters (*e.g.*, regarding liquor concentration and the production of ammonium bicarbonate) the Committee has been in contact with the Controller of Industrial Ammonia.

The Committee has to report that Dr. A. Key, who was for many years engaged upon research work on effluents and ammonia, was, in September, 1945, appointed Chemical Inspector to the Ministry of Health. The thanks of the Committee are due to Dr. Key for his valuable services to the Industry. Dr. Key's work on behalf of the Committee is now being carried out by Dr. A. H. Eastwood.

Composition of Ammoniacal Liquor

The type of carbonizing plant exercises a marked influence on the composition of the liquor. Further, the liquors obtained from the several parts of the plant show important differences. Thus, although little condensation occurs in the retort house, the liquor circulated through the hydraulic mains becomes rich in the less volatile substances (notably ammonium chloride and higher tar acids), and low in the volatile ammonium salts. The gas entering the condensers should contain little tar and, therefore, the liquor condensed there should contain only small quantities of higher tar acids, since these, being non-volatile in steam, condense with the tar. Similarly the fixed ammonia is low. The concentrations of free ammonia, carbonate, sulphide and phenols are, however, relatively high. The ammonium compounds still in the gas leaving the condensers are removed in the scrubbers, the liquor from which contains the bulk of the free ammonia, carbonate, and sulphide. A little cyanide is also commonly present. The thiocyanate and thiosulphate found in this liquor are not primary products, but are formed by oxidation of the original sulphide and cyanide. Their concentration, therefore, depends on the opportunities available for this oxidation to occur.

Utilization of Ammoniacal Liquor

In the past, the ammonia contained in ammoniacal liquor was generally recovered as sulphate. With the rise of the synthetic ammonia industry, however, this, in the case of small and medium-sized works, ceased to be profitable, except in isolated instances. At some works the ammoniacal liquor was even run to waste. The Committee strongly deprecates such wastage of ammonia. The economics of sulphate manufacture and the possibilities of other methods of treatment have, therefore, been closely considered. The solution recommended by the Committee is the production of saleable ammonium compounds at central works, the cost of transport to these being kept low by the concentration of the liquor before despatch. For this concentration automatic plants, which are inexpensive and easy to operate, are available. Generally, these convert the ammoniacal liquor into a concentrated gas liquor containing some 15 to 24% ammonia, together with considerable quantities of carbonate and sulphide and some phenols, and a spent liquor containing the fixed ammonium salts, the higher tar acids and the bulk of the phenols. Considerable numbers of these plants are now in successful operation, and the problem of liquor disposal is thus simplified, sometimes with financial advantage.

For certain works another possible method of utilization exists. Ammoniacal liquor has been shown to be a useful nitrogenous fertilizer if applied at a suitable time and in correct dosage, and, where a works is so situated that the liquor as such can be used locally without heavy transport charges, this may provide a useful outlet.

---

* Communication No. 188. (Price 5s., post free.)

† See Appendix to this Report.

Of the other constituents of liquor only the phenols are likely to be extracts at a possible profit. The known methods of recovery were studied in the earlier work of the Committee, and it was found that the process in which the phenols were washed out by benzole was the most widely used. Benzole, however, is not an ideal solvent. Its solvent power is low, and loss by volatilization and solution in the liquor was high. Alternative solvents were considered, in particular tricresyl-phosphate and certain de-phenolated tar oil fractions. Both of these have an improved solvent power, and loss by volatilization and solution in the liquor was low. There were, however, difficulties. Tricresyl-phosphate became contaminated in use, while the tar oil fractions were not easy to prepare. Since then the new " Phenosolvan " process has been developed. In this the phenols are recovered by solution in a mixture of aliphatic esters termed " Phenosolvan." This has a high solvent power for phenols, and its boiling-point is less than that of the recovered phenols, so that it does not become contaminated in use, being recovered after each treatment in pure form. Further investigation is being made of the suitability of various solvents for the recovery of phenols from ammoniacal liquor.

Disposal of Gas-Works Liquor

Except where all the liquor is used as a fertilizer, there remains, whatever treatment is given, the problem of the final disposal of spent liquor. The recognized methods available are:

(1) Evaporation.
(2) Direct discharge into a suitable body of water.
(3) Discharge into the sewers for treatment in admixture with sewage at the local sewage works.

Of these three methods, evaporation should only be used when no better alternative presents itself. It is apt to be expensive, and may cause trouble due to corrosion and aerial pollution. Should it be used, an important consideration is that the volume of the liquor should be a minimum, and methods for achieving this have been described in reports of the Committee.

Direct discharge to surface waters is not usually permissible in view of the very polluting character of the liquor. Phenols and higher tar acids are particularly undesirable in water which is to be used as a source of domestic supply, since when chlorinated these substances impart an unpleasant taste to the water, even when they are present in very minute concentrations. Damage may also be done to fisheries by discharge of gas-works liquor, both as a result of de-oxygenation of the water and of the direct toxic action of some of the constituents of the liquor.

The principal toxic substances are the phenols and higher tar acids, which may severely affect fish when present in concentrations above 1 part per 100,000. Where, however, sufficient dilution is possible, as in the case of discharge into the sea, this method provides a simple solution to the problem. Care, however, must be taken to avoid high local concentrations of liquor, and perhaps the best method of achieving this is to discharge the liquor into the local sewers, where preliminary dilution with sewage takes place. Clearly de-phenolation, particularly if accompanied by some measure of removal of the higher tar acids, would be of material assistance in this method of disposal.

Discharge into Sewer

The third method is that most strongly recommended by the Committee. The discharge of liquor to the sewers in England and Wales (excluding London) is now governed by the Public Health (Drainage of Trade Premises) Act (1937), which came into force on July 1, 1938. This Act does not affect the right of gas undertakings to discharge into the sewers effluent of the same composition and quantity as that discharged before March 3, 1937. With regard to new or increased discharges, however, the Act provides that traders may discharge effluents into the sewers either (*a*) in accordance with by-laws made by the local authority or (*b*) by agreement with the local authority. It is thought that some local authorities, while not making any by-laws under the Act, may suggest that gas undertakings should enter into agreement with them, and endeavour to insert in such agreements provisions similar to those frequently imposed by by-laws. The Committee wishes to call attention to the fact that no gas undertaking is compelled to enter into such an agreement with the local authority, but is, on the other hand, entitled to request the Ministry of Health to call upon the local authority to make the necessary by-law. Where an agreement is suggested, or as soon as notice is received that a local authority proposes to make by-laws, the Committee recommends that the gas undertaking should communicate with the Secretary of the Institution of Gas Engineers, since the Committee particularly desires to consider such by-laws and any proposed scale of payments, so as to avoid any prejudice to the general interests of the Gas Industry.

Investigation has shown that, in a normal case, where the areas served by the gas-works and the sewage works are congruent, the percentage of spent liquor in the sewage will not exceed about 0.4%, and that with this mixture no difficulty should be experienced in treating the liquor. In this country, sewage, after removal of the suspended solids, is commonly purified by biological oxidation, either in percolating filters or by activated sludge plants. Experiments on the behaviour of the separate constituents of spent liquor have shown that:

(1) Fixed ammonia may or may not be completely oxidized, depending upon the capacity of the plant. If oxidation is incomplete, the oxygen demand of the effluent will be increased, with a corresponding deterioration in its quality.
(2) Phenols are very readily oxidized.
(3) Higher tar acids and thiocyanate are the most difficult to treat.
(4) Thiosulphate may usually be neglected, as its concentration is low; and, moreover, since it is formed in an analogous manner to thiocyanate, any steps taken to reduce the concentration of the latter will also affect that of the thiosulphate.

The Electric Detarrer

Clearly, the most suitable spent liquor for disposal in admixture with sewage is one containing the minimum possible amounts of higher tar acids and thiocyanate. Reduction of this latter substance will also reduce that of the fixed ammonia, with consequential benefit. The content of higher tar acids depends largely on the degree of contact between the liquor and the tar, and, therefore, there should be complete and early separation of the two. One method of securing this is by the use of an electrical de-tarrer in the hot gas, coupled with complete isolation of the retort house liquor from the scrubber and condenser liquor. From what was said above, it will be seen that by this means only the retort house liquor will contain higher tar acids, and it is possible to deal with this separately. It may be used as a fertilizer, or evaporated with or without recovery of the ammonium chloride contained in it. The latter treatment may, if necessary, be carried out after conveyance of the liquor to a central works.

It has already been stated that the content of thiocyanate depends on the extent to which the liquor has undergone oxidation. The Committee therefore recommends that air for purification should be admitted, not at the inlet to the condensers, but at the inlet to the purifiers. Further, the time of contact of the scrubbing liquid and gas should be the minimum consistent with removal of the ammonia, and if liquor is used as the scrubbing medium, then its initial sulphide content should be as low as possible. Thiocyanate formation can also be reduced by the separate recovery of cyanide for sale as thiocyanate.

For efficient treatment of liquor in admixture with sewage the ratio of the one to the other should remain substantially constant. This is particularly necessary where thiocyanate is to be oxidized, since this process requires the presence of a special strain of bacteria, and these cannot flourish with sudden variations in the proportion of liquor to sewage.

Crude ammoniacal liquor can be treated in admixture with sewage, but with greater difficulty than spent liquor. The proportion which can be tolerated is less, and even so the degree of purification is smaller. This is mainly due to the presence of sulphide and a larger proportion of ammonia in the " free " state. These substances are removed by distillation, and the consequent improvement in the ease of treatment of the liquor is so pronounced that the Committee considers distillation the best single means at present available for facilitating the disposal of gas-works liquor.

Experience at Hinckley

A striking example of what can be achieved by the application of these recommendations was given by Mr. A. B. Britton (Engineer and Manager of the Hinckley Corporation Gas Undertaking), in his Presidential Address to the Midland Association of Gas Engineers and Managers, on March 15, 1945. The problem at Hinckley was peculiarly difficult in that 40% of the flow at the sewage works was composed of dye wastes, and thus, with a normal vertical retort liquor, it was not possible to treat more than a trace in admixture with the sewage. The liquor, therefore, had to be removed by rail tank-cars to chemical works at a considerable expense. Following the Committee's recommendations, the following alterations were made at the works: An electrical de-tarrer, to treat the hot gas, was installed, and the retort house liquor was isolated from the main bulk. This retort house liquor, rich in higher tar acids and ammonium chloride, is not passed into the sewers. Prior to the war it was sent by tank-car to Birmingham, but it is now disposed of locally as a fertilizer. The thiocyanate content of the main bulk of the liquor was greatly reduced by the installation of a small blower to pass the air for purification into the gas at the inlet to the purifiers. This liquor was distilled in an automatic concentrated-liquor plant, and the effluent finally passed to the sewer was of such an improved character that no trouble has been experienced in treating the whole of it at the sewage works. Moreover, Mr. Britton pointed out that these alterations had resulted in a saving of about 0.35d. per them of gas sold.

Centralized Gas Manufacture

A recent development in the Industry is the tendency to concentrate manufacture in a small number of larger works. In such circumstances the proportion of liquor produced may well exceed that which can be tolerated at the local sewage works. In many cases the application of the normal methods already discussed will be sufficient to make treatment of the liquor possible, but should this not be so, methods of further

purification will be necessary. The process of phenol recovery by extraction with benzole effects a marked reduction in the oxygen demand of the effluent, but from what has been said, it will be appreciated that this does not greatly assist in the treatment of liquor in admixture with sewage by biological means. The more recent processes of de-phenolation—namely, the "Triphos" (using tricresylphosphate) and the "Phenosolvan"—will, however, remove without excessive expenditure of solvent a worthwhile quantity of higher tar acids, and thus effect a substantial improvement in the quality of the liquor. A further reduction in the pollution power of the spent liquor would be obtained by removal of the thiocyanate, and a process for achieving this by its precipitation as an insoluble salt has been examined and shown to be workable.

Research

Reference has been made to investigations undertaken by the Gas Research Board of problems relating to effluents. The Liquor Effluents and Ammonia Committee continues to review the whole field of gas-works effluents and ammonia as well as special lines of investigation. It also affords advice and assistance in response to many enquiries from gas undertakings, and makes recommendations to the Gas Research Board in regard to further research on these matters. In problems which arise calling for research the Committee now has the assistance and co-operation of the Gas Research Board.

A list of the reports of the Committee and of its predecessors, the Liquor Effluents Research Sub-Committee and the Ammonia Sub-Committee, is given in the following Appendix.

APPENDIX

Reports of the Liquor Effluents and Ammonia Committee and its Two Predecessors

Reports of the Liquor Effluents Research Sub-Committee

1st and 2nd Reports.
Trans. Inst. Gas Eng. (1927-1928), 77; 330-432.
A general review of the problem of disposal of gas-works effluents and the results of preliminary experiments at Hinckley.

3rd Report.
Trans. Inst. Gas Eng. (1928-1929), 78; 256-265.
The examination of methods of improving the composition of liquor for treatment by biological means and some observations on the use of such treatment at the Foleshill Gas-works, Coventry.

4th Report.
Trans. Inst. Gas Eng. (1929-1930), 79; 375-422.
A report on processes for the removal of phenols from gas-works liquors, with a description of methods in use in Germany.

5th Report.
Trans. Inst. Gas Eng. (1930-1931), 80; 186-238.
Further experiments on the improvement of the composition of liquor for its disposal by evaporation or biological means. Notes on German phenol-recovery plants.

Reports of the Ammonia Sub-Committee

1st and 2nd Reports.
Trans. Inst. Gas Eng. (1929-1930), 79; 254-334.
General discussion of the position of ammonia recovery, either as sulphate, concentrated liquor or some other ammonium compound. Description of alternative methods of gas purification.

3rd Report.
Trans. Inst. Gas Eng. (1930-1931), 80; 239-279.
Further discussion of alternative means of gas purification and ammonia recovery.

Reports of the Liquor Effluents and Ammonia Committee

1st Report.
Trans. Inst. Gas Eng. (1931-1932), 81; 190-240.
Further work on methods of improving liquor composition, with particular reference to the removal of phenols and higher tar acids, and on the biological purification of liquor or its disposal by evaporation. Recovery of ammonium chloride from circulating liquor.

2nd Report.
Trans. Inst. Gas Eng. (1932-1933), 82; 393-465.
Experiments on the biological purification of gas-works liquors and on the recovery of phenols from ammoniacal liquor.

3rd Report.
Trans. Inst. Gas Eng. (1933-1934), 83; 130-205.
Experiments on the biological purification of constituents of gas-works liquor. The manufacture and utilization of ammonium bicarbonate. Removal of phenols by distillation.

4th Report.
Trans. Inst. Gas Eng. (1934-1935), 84; 187-245.
Further work on the biological purification of gas-works liquor in admixture with sewage, with particular reference to thiocyanate.

5th Report.
Trans. Inst. Gas Eng. (1935-1936), 85; 396-465.
The effects of gas-works liquor on (1) disposal of sewage by dilution, (2) treatment by activated sludge, and (3) treatment by bacteria beds, including a large-scale test at Leamington Spa.
Memorandum by P. Parrish, M.Inst.Gas E., M.I.Chem.E., F.R.I.C., on the by-product ammonia problem, with special reference to ammonium bicarbonate.

6th Report.
Trans. Inst. Gas Inst. (1936-1937), 86; 203-296.
Experiments on the fertilizing properties of ammonium bicarbonate, concentrated liquor and crude ammoniacal liquor. Effect of gas-works liquor on sewage treatment by chemical methods, including chlorination.

7th Report.
Trans. Inst. Gas Eng. (1937-1938), 87; 525-589.
Investigation of the performance of a concentrated liquor plant with some notes on the properties of a concentrated liquor.

The Future Development of Gas Manufacture*

By S. G. IRWIN

OWING to variations in the demand for gas it is necessary for an undertaking to install stand-by plant which is only used for a comparatively short period of time, thus increasing the cost per therm of gas made. This stand-by plant must include units which are capable of meeting sudden large demands for gas (*i.e.*, peak loads). Any attempt, therefore, to predict future developments in methods of gas manufacture must include a consideration of the most efficient and economical methods of meeting these peak loads. In normal gas-works practice, any combination of the following methods may be used:

(1) The addition of carburetted water gas to the coal gas.
(2) The maintenance of refractory settings under sufficient heat to enable them to be brought into operation at short notice.
(3) Increasing the output from carbonizing plant already in use.
(4) The inter-connexion of works' distribution systems by means of a gas grid.

The principal advantages and disadvantages of each of the above methods may be briefly summarized as follows:

Method 1
The Addition of Carburetted Water Gas:

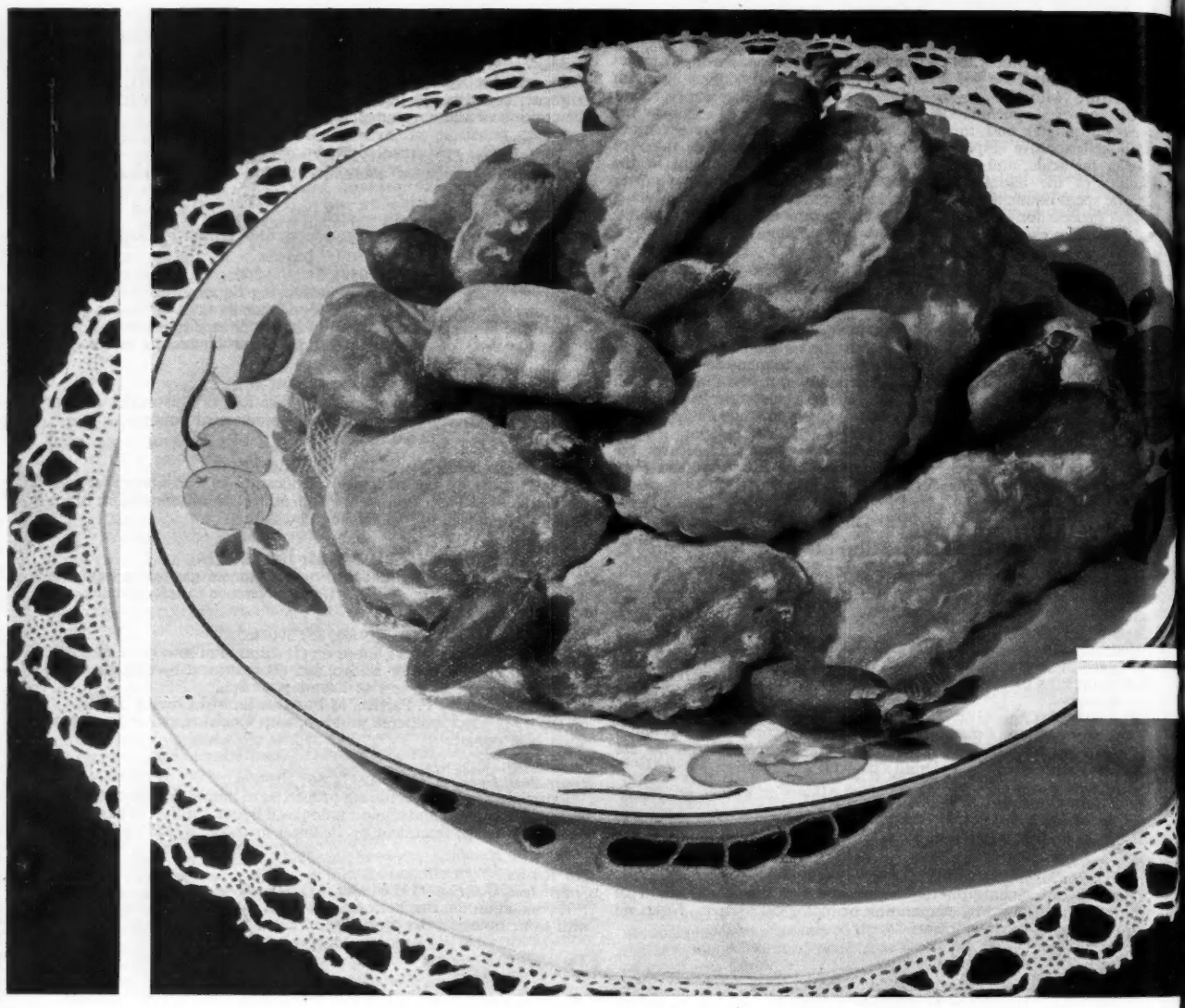
Advantages
(*a*) High flexibility of plant. Full output of carburetted water gas available within twelve hours.
(*b*) Increased gasification of coal, with consequent reduction in the coal consumption for a given gas output—an advantage of special importance during the present, and possible future, coal shortage.
(*c*) Further outlet for coke where unfavourable coke market exists.
(*d*) High thermal yield per unit of ground area.
(*e*) Low labour requirements.

Disadvantages
(*a*) The relatively high cost of carburetting (after deducting the subsidy at present paid on gas oil).
(*b*) The combustion characteristics of the town gas are unfavourably altered due to changes in the composition when the coal and carburetted water gas are mixed. In extreme cases trouble may arise on the district.
(*c*) Technical difficulties may be experienced in maintaining the required calorific value and output due to variations in the quality of coke and/or gas oil. This difficulty becoming more acute with increase in the calorific value required.
(*d*) Increased toxicity of the town gas due to the higher carbon monoxide content.

Here it may be pertinent to add that where carburetted water gas plants are installed, the plant and holder capacity should be adequate to allow the plant to work continuously at full capacity when in use.

If the plant is too large it may only be possible, on many occasions, to work one or two shifts per day. This will reduce the efficacy of the waste heat boiler and the overall technical efficiency of the process. The carburetting efficiency may also be lowered.

* From a Paper presented to the North of England Gas Managers' Association (Auxiliary Section), Dec. 13, 1946.



the NEW

established

Radiation Ltd. RADIATION HOUSE, ASTON, BIRMINGHAM, 6
SHOWROOMS & LONDON OFFICE: 7, STRATFORD PLACE, W.1.

Hence it may be preferable to install the necessary number of small units able to meet, singly and collectively, the minimum and maximum peak demands respectively. This system would also give a greater margin of safety in the event of plant breakdowns.

The use of blue water gas for meeting peak loads is limited due to its low calorific value. At present, 80% of undertakings distribute gas at a calorific value between 450 and 500 B.Th.U.

Method 2

The Maintenance of Refractory Settings under Heat:

Advantages

(*a*) The combustion characteristics of the gas are unaltered, the gas composition remaining unchanged.

Disadvantages

(*a*) The high capital cost of stand-by plant—the whole cost of these settings cannot, of course, be debited to meeting the peak load since a certain number are always required to allow for repairs to plant.

(*b*) Heavy rate of depreciation of carbonizing plant due to intermittent use. (It has been stated that letting down a setting may reduce its working life by as much as 400 days).

(*c*) Rapid reduction in the technical efficiency of the stand-by settings (particularly the regenerators).

(*d*) Possible reduction in the overall technical efficiency of the working settings and waste heat boilers, due to air infiltration through the stand-by settings when these latter are cold (even though the waste gas dampers are sealed).

(*e*) The amount of saleable coke is reduced, since coke is required to maintain "standing" settings under heat. Where waste heat boilers are installed, a certain amount of heat is recovered, but steam requirements can usually be met more economically by burning surplus breeze.

Method 3

Increasing the Output from Existing Plant, e.g.:

(i) Reducting the carbonizing periods on horizontal settings.

(ii) Increasing the coal throughput and amount of steaming on vertical settings.

(iii) Reducing the amount of benzole extracted.

Advantages

(*a*) Reduction in the amount of stand-by plant.

(*b*) High flexibility—increased gas make available almost immediately.

(*c*) Comparatively small increase in the amount of labour required.

Disadvantages

(*a*) The increase in output is limited, and may not be sufficient to meet the heavier peak loads.

(*b*) The technical efficiency of the plant is reduced, the extent of this reduction depending upon the magnitude and duration of the extra gas load, *e.g.*, the thermal equilibrium of the setting is disturbed and, even if restored, the increased fuel consumption in the producers is not balanced by an equivalent increase in the gas make. Any increase in the coal throughput is accompanied by a lower thermal gaseous yield per ton of coal carbonized and, if practised, a reduction in the efficiency of steaming.

(*c*) An increase in the organic sulphur content of the gas if benzole extraction is stopped. The load factor of the benzole plant is also reduced, with consequent increase in the cost per gallon of benzole made. Furthermore, the loss in revenue due to the reduced benzole make may not be entirely offset by the revenue from benzole sold as gas.

Method 4

Distribution of Gas Grid:

Advantages

(*a*) Reduction in the amount of stand-by plant and storage capacity required.

Disadvantages

(*a*) The grid system is limited to undertakings having more than one manufacturing station, or to a group of undertakings so geographically situated with respect to one another, that the position of the areas of demand makes it economically possible to meet these demands via an inter-linked distribution system.

(*b*) The combustion characteristics of the gas will vary, if different methods of carbonization are used at the several works serving the grid.

From this brief survey, it will be seen that none of these methods provides a really flexible process capable of producing a gas of high calorific value and constant combustion characteristics, without an accompanying reduction in the operating efficiency of the gas-making process.

For this reason, two investigations at present being carried out by the Gas Research Board are of special interest, namely, the complete gasification of coal under pressure of hydrogen, and the catalytic synthesis of methane from carbon monoxide and hydrogen.

It is thereby hoped to produce, on an economic basis, a gaseous mixture, similar in composition to that obtained from the direct carbonization of coal, without the complications associated with coke production.

The Board has also envisaged the possibility of the latter synthetic process being used to replace the relatively expensive carburetting process for raising the calorific value of gas produced in blue water gas plants.

The demand for gas has increased considerably since the outbreak of war and shows no sign of diminishing. The reduced quantity and increased cost of the coal available to meet this demand has once more focussed attention on the desirabilty of evolving more economical methods of gas manufacture which will result in a higher thermal gaseous yield per ton of coal carbonized.

Meeting the Overall Increased Demand

Some of the major difficulties which have prevented any considerable developments in this direction with existing types of carbonizing plant may be mentioned:

1. *Steaming of Retorts*

(*a*) It is possible by the use of steam to increase the thermal efficiency of the gas making process in continuous and intermittent vertical retorts. In this way, blue water gas is manufactured, principally by utilizing the sensible heat in the coke—heat which otherwise would be largely wasted. Also, the internal heating of the coal charge by the water gas further assists carbonization and increases the overall thermal efficiency of the process.

There is, however, a limit to the amount of steam which can be usefully added, a stage being reached when the extra water gas is made at the expense of the coke in the producers, and coke is gasified in the retorts at a considerably reduced thermal efficiency—lower than that of a blue water gas plant.

(*b*) The increased thermal yield due to steaming is accompanied by a reduction in the calorific value of the gas, and a consequent increase in the cost of purifying and distributing each therm.

Here it must be added that a gas of lower calorific value is not necessarily less "efficient" than one of high calorific value. The effect of specific gravity upon the cost of distribution, and flame temperature upon the utilization efficiency of the gas, are but two other factors to be considered.

Hence a case may be made out for distributing gases of lower calorific value, although at present only a minority of undertakings manufacture gas below 450 B.Th.U.

2. *Thermal Output*

(*a*) It is not always possible to increase the thermal yield per ton of coal carbonized without reducing the thermal yield per unit of plant. Any reduction in the latter yield means that additional plant must be installed to maintain the thermal output at its original level. In consequence, additional capital, maintenance, and labour expenses are incurred, and these may be sufficient to increase the net cost per therm made.

The thermal yield which gives the lowest nett cost per therm into the holder would appear to depend largely upon the type of carbonizing plant used. According to F. B. Richards ("Perspective in Carbonizing Costs," "GAS JOURNAL," Oct. 31, 1934), when carbonizing South Yorkshire screened coals, and making gas between 500 and 450 B.Th.U., an increased gaseous thermal yield per ton was accompanied by (1) a reduction in the net cost per therm on continuous verticals, and (2) an increase in the net cost per therm on intermittent verticals.

In the continuous verticals, the thermal output per unit of plant was maintained at all calorific values between 500 and 450 B.Th.U. In the intermittent verticals, the thermal output dropped with increased gasification.

Similarly, with the tests carried out at Croydon in a test installation of static vertical retorts (*Institution Transactions*, 1938-39, p. 1033), increased gasification was accompanied by a reduction in the thermal yield per unit of plant.

In the case of the latter installation, however, this disadvantage may be more than offset, since the static vertical retort gives an appreciably higher thermal yield per ton of coal carbonized than either continuous or intermittent verticals for any given calorific value between 525 and 475 B.Th.U. So far as the writer is aware, no figures have yet been published to show the cost of obtaining these therms.

In view of all these aforementined difficulties, it would appear that for some time to come the Industry can only meet any considerable increased demand for gas by an extension of the existing gas making processes.

Meanwhile, owing to the shortage of labour and materials required for the construction of new plant, the Industry is compelled to resort more frequently to the use of peak load methods of gas manufacture, in order to satisfy these demands.

Coke Production

Failing the introduction of an economic complete gasification process, any big expansion in the demand for gas can only be met by increasing the amount of coke produced.

At present, the income from coke sales is sufficient to offset the cost of coal by approximately 50%, and has always constituted by far the greatest item of revenue in reducing the cost of making gas.

Unless the Industry is able to find new markets—or extend existing ones—which will absorb the extra coke produced, it will not be possible to maintain the existing price levels for coke, and in consequence, the cost of making gas will be increased.

It is evident, however, that there is still a considerable potential field of development for the domestic use of coke in place of coal, and the adoption of a national smoke abatement policy would still further assist this development.